WILKINS

MATHEM-
ATICAL
MAGICK

1648

Mathematicall MAGICK.

OR,

THE VVONDERS

That may be performed by *Mechanicall Geometry.*

In two Books.

CONCERNING

Mechanicall { POVVERS. MOTIONS.

BEING ONE OF

The moſt eaſie, pleaſant, uſefull, (and yet moſt neglected) part of *MATHEMATICKS.*

Not before treated of in this language.

By *I.W. M.A.*

Τέχνῃ κρατοῦμεν ὧν φύσει νικώμεθα.

LONDON,
Printed by *M.F.* for *Sa: Gellibrand* at the braſen Serpent in *Pauls* Church-yard. 1648.

TO HIS HIGHNESSE The Prince Elector Palatine.

May it please your Highnesse,

I *Should not thus have presented my* diversions, *where I owe my study and* business, *but that where all is due, a man may not justly withhold any part.*

This following Discourse was composed some years since at my spare howers in the University. The subject of it is mixed Mathematicks *which I did the rather at such times make choice of, as being for the* pleasure *of it, more proper for recreation, and for the* facility *more sutable to my abilities and leisure.*

I should not Sir, have been ambitious of any so Great *(I could not of any* Better*) Patronage, had not my relation both engaged and emboldned me to this Dedication.*

They that know your Highnesse how great an encourager you are, and how able *a Judge in all kind of ingenuous arts and literature, muſt needs acknowledge your preſſures and low condition, to be none of the leaſt miſchiefs (amongſt thoſe many other) under which the Common-wealth of learning does now ſuffer.*

It would in many reſpects much conduce to the generall advancement of religion and learning, if the reformed Churches in whoſe cauſe and defence your family hath ſo deeply ſuffered, were but effectually mindfull of their engagements to it. And particularly, if theſe preſent unhappy differences of this Nation did not occaſion too much forgetfulneſſe of their former zeal and profeſſions for the vindicating *of your family, and the* re-ſtoring *of your Highneſſe; the haſtning and accompliſhment of which, together with the increaſe of all heavenly bleſſings upon your Highneſſe, ſhall be the hearty dayly prayer of*

Your Highneſſe

moſt humble and moſt devoted

ſervant and Chaplain,

JOHN WILKINS.

TO THE READER.

IT is related of *Heraclitus* that when his Scholars had found him in a tradeſmans ſhop, whether they were aſhamed to enter. He told them, *Quod neque tali loco dii deſunt immortales*, that the gods were as well converſant in ſuch places as in others; Intimating that a divine power and wiſdome might be diſcerned even in thoſe common arts, which are ſo much deſpiſed; And though the manuall exerciſe and practiſe of them be eſteemed ignoble, yet the ſtudy of their generall cauſes and principles, cannot bee prejudiciall to any other (though the moſt ſacred) profeſſion.

It hath been my uſuall cuſtome in the courſe of my other ſtudies, to propoſe divers Mathematicall or Philoſophicall inquiries, for the recreation of my leiſure howers, and as I could gather ſatisfaction to compoſe them into ſome form and method.

Some of theſe have been formerly publiſhed, and I have now ventured forth this diſcourſe; wherein beſides the great *delight and pleaſure* (which every rationall Reader muſt needs finde in ſuch notions as carry with them their own evidence and demonſtration) there is alſo much *real benefit* to be learned; particularly for ſuch Gentlemen as employ their eſtates in thoſe chargeable adventures of Drayning, Mines, Cole-pits, &c. who may from hence learn the chief grounds & nature of Engines, & thereby more eaſily avoid the deluſions of any cheating Impoſtor: And alſo for ſuch *common artificers*, as are well skilled in the *practiſe* of theſe arts, who may be much advantaged by the right underſtanding of their grounds and *Theory*.

Ramus hath obſerved, that the reaſon why *Germany* hath been ſo eminent for Mechanicall inventions, is becauſe there have been publike Lectures of this kind inſtituted amongſt them, and thoſe not only in the learned languages, but alſo in the vulgar tongue, for the capacity of every unlettered ingenious Artificer.

Scho. Mathem. l. 2.

This whole Diſcourſe I call *Mathematicall Magick*, becauſe the art of ſuch Mechanicall inventions as are here chiefly inſiſted upon, hath been formerly ſo ſtyled; and in alluſion to vulgar opinion, which doth commonly attribute all ſuch ſtrange operations

Agrippa, De Vanit. Scient. ca. 42.

unto

unto the power of Magick ; For which reason the Ancients did name this art Θαυματοποιητικὴ, or *Mirandorum Effectrix.*

The first book is called *Archimedes*, because he was the chiefest in discovering of Mechanicall *powers*.

The second is styled by the name of *Dædalus*, who is related to be one of the first & most famous amongst the Ancients for his skil in making *Automata*, or self-moving Engines : both these being two of the first Authors that did reduce Mathematicall principles unto Mechanicall experiments.

Other discourses of this kind, are for the most part large and voluminous, of great price and hardly gotten ; and besides, there are not any of them (that I know of) in our vulgar tongue, for which these Mechanicall arts of all other are most proper. These inconveniences are here in some measure remedied, together with the addition (if I mistake not) of divers things very considerable, and not insisted upon by others.

The

THE CONTENTS And Method of this following Discourse.

The first Book.

Ch. 6.

The Contents.

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The Contents.

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ways

ARCHI-

ARCHIMEDES, OR, MECHANICALL Powers.

The first Book.

Chap. I.

The excellency of these Arts. Why they were concealed by the Ancients. The Authours that have treated of them.

ALL those various studies about which the sons of men doe busie their endevours, may be generally comprised under these three kinds:

- Divine.
- Naturall.
- Artificiall.

To the firſt of theſe, is reducible, not onely the *ſpeculation* of Theologicall truths, but alſo the *practiſe* of thoſe virtues, which may advantage our minds, in the enquiry after their proper happineſſe. And theſe arts alone may truly be ſtyled liberall, *Quæ liberum faciunt hominem, quibus curæ virtus eſt*, (ſaith the divine Stoick) which ſet a man at liberty from his luſts and paſſions.

Sen. Ep. 88.

To the ſecond may be referred all that knowledge, which concerns the frame of this great Univerſe, or the uſuall courſe of providence in the government of theſe created things.

To the laſt doe belong all thoſe inventions, whereby nature is any way quickned or advanced in her defects: Theſe artificiall experiments being (as it were) but ſo many Eſſays, whereby men doe naturally attempt to reſtore themſelves from the firſt generall curſe inflicted upon their labours.

This following Diſcourſe, does properly appertain to this latter kind.

Now

Now **Art** may be ſaid, either to *imitate* nature, as in limming and pictures; or to *help* nature, as in medicine; or to *overcome*, and *advance* nature, as in theſe Mechanicall diſciplines, which in this reſpect are by ſo much to be preferred before the other, by how much their end and power is more excellent. Nor are they therefore to bee eſteemed leſſe noble, becauſe more practicall, ſince our beſt and moſt divine knowledge is intended for action, and thoſe may juſtly be counted barren ſtudies, which doe not conduce to practiſe as their proper end.

But ſo apt are we to contemn every thing which is common, that the ancient Philoſophers eſteemed it a great part of wiſdome to conceale their learning from vulgar apprehenſion or uſe, thereby the better to maintain it, in its due honour and reſpect. And therefore did they generally vail all their Arts and Sciences, under ſuch myſticall expreſſions, as might excite the peoples wonder and reverence, fearing leſt a more eaſie and familiar diſcovery, might expoſe them to contempt. *Sic ipſa myſteria fabularum cuniculis operiuntur, ſummatibus tantum viris, ſapientia interprete, veri arcani conſciis; Contenti ſint reliqui, ad venerationem, figuris defendentibus à vilitate ſecretum,* ſaith a Platonick.

Macrobius Somn. Scip. l. 1. c. 2.

Hence was it, that the ancient Mathematicians did place all their learning in abſtracted ſpeculations, refuſing to debaſe the principles of that noble profeſſion unto Mechanicall experiments. Inſomuch, that thoſe very Authors amongſt them, who were moſt eminent for their inventions of this kind, and were willing by their own practiſe, to manifeſt unto the world, thoſe artificiall wonders, that might be wrought by theſe arts, as *Dædalus, Archytas, Archimedes, &c.* were notwithſtanding ſo much infected with this blind ſuperſtition, as not to leave any thing in writing, concerning the grounds and manner of theſe operations.

Quin-

Quintilian ſpeaking to this purpoſe of *Archimedes*, ſaith thus. *Quamvis tantum tamque ſingularem Geometriæ uſum, Archimedes, ſingularibus exemplis, & admirandis operibus oſtenderit, propter quæ non humanæ ſed divinæ ſcientiæ laudem ſit adeptus, hæſit tamen in illa Platonis perſuaſione, nec ullam Mechanicam literam prodere voluit.* *Quint. l. 1. c. 10.*

By which means, poſterity hath unhappily loſt, not onely the benefit of thoſe particular diſcoveries, but alſo the proficiency of thoſe arts in generall. For when once the learned men did forbid the reducing of them to particular uſe, and vulgar experiment: others did thereupon refuſe theſe ſtudies themſelves, as being but empty and uſeleſſe ſpeculations. Whence it came to paſſe that the ſcience of Geometry was ſo univerſally neglected, receiving little or no addition for many hundred years together. *Pet. Ram. Schol. Mathem. l. 1.*

Amongſt theſe Ancients, the divine *Plato* is obſerved to be one of the greateſt ſticklers for this fond opinion, ſeverely dehorting all his followers from proſtituting Mathematicall principles, unto common apprehenſion or practiſe. Like the envious Emperour *Tiberius*, who is reported to have killed an Artificer for making glaſſe malleable, fearing leſt thereby the price of metals might be debaſed. So he, in his ſuperſtition to Philoſophy, would rather chuſe to deprive the world of all thoſe uſefull and excellent inventions, which might be thence contrived, then to expoſe that profeſſion unto the contempt of the ignorant vulgar.

Plin. Nat. l.36.c.26.

But his Scholar *Ariſtotle*, (as in many other particulars, ſo likewiſe in this) did juſtly oppoſe him, and became himſelf one of the firſt Authours, that hath writ any methodicall Diſcourſe concerning theſe arts, chuſing rather a certain and generall benefit, before the hazzard that might accrue from the vain and groundleſſe diſ-reſpects of ſome ignorant perſons. Being ſo far from eſteeming Geometry diſhonoured by the applicati-

Ariſt. Quæſt. Mechan.

on

on of it to Mechanicall practiſes,that he rather thought it to be thereby adorned, as with curious variety,and to be exalted unto its naturall end. And whereas the Mathematicians of thoſe former ages, did poſſeſſe all their learning, as covetous men doe their wealth, only in thought and notion; the judicious *Ariſtotle*, like a wiſe Steward, did lay it out to particular uſe and improvement, rightly preferring the reality and ſubſtance of publike benefit, before the ſhadows of ſome retired ſpeculation, or vulgar opinion.

Since him there have been divers other Authors, who have been eminent for their writings of this nature. Such were *Hero Alexandrinus*, *Hero Mechanicus*, *Pappus Alexandrinus*, *Proclus Mathematicus*, *Vitruvius*, *Guidus Vbaldus*, *Henricus Monantholius*, *Galileus*, *Guevara*, *Merſennus*, *Bettinus*, &c. Beſides many others, that have treated largely of ſeverall engines, as *Auguſtine Ramelli*, *Vittorio Zoncha*, *Jacobus Beſſonius*, *Vegetius*, *Lipſius*.

Moſt of which Authours I have peruſed, and ſhall willingly acknowledge my ſelf a debtor to them for many things in this following Diſcourſe.

CAP. II.

Concerning the name of this Art. That it may properly be ſtyled liberall. The ſubject and nature of it.

THe word *Mechanick* is thought to be derived ἀπὸ τοῦ μήκους καὶ ἄνειν, *multum aſcendere, pertingere*: intimating the efficacy and force of ſuch inventions. Or elſe παρὰ μὴ χαίνειν, (ſaith *Euſtathius*) *quia hiſcere non ſinit*, becauſe theſe arts are ſo full of pleaſant variety, that they admit not either of ſloth or wearineſſe.

Lypſius. Polyorcet. l.1. Dialog 3.

That's a ſenſleſſe abſurd Etymology impoſed by ſome, *Quia intellectus in eis mœchatur*, as if theſe arts did proſtitute and adulterate the underſtanding.

According to ordinary ſignification, the word is uſed in oppoſition to the liberall arts: whereas in propriety of ſpeech thoſe employments alone may be ſtyled *illiberall*, which require onely ſome bodily exerciſe, as manufactures, trades, &c. And on the

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contrary that diſcipline, which diſcovers the generall cauſes, effects, and properties of things, may truly be eſteemed as a *ſpecies* of Philoſophy.

But here it ſhould be noted, that this art is uſually diſtinguiſhed into a twofold kind:

1. *Rationall.*
2. *Cheirurgicall.*

The *Rationall* is that which treats of thoſe principles, and fundamentall notions, which may concern theſe Mechanicall practiſes.

Pappus Proœm. in Collect. Mathem. l. 8.

The *Cheirurgicall* or *Manuall*, doth refer to the making of theſe inſtruments, and the exerciſing of ſuch particular experiments. As in the works of Architecture, Fortifications, and the like.

The firſt of theſe, is the ſubject of this diſcourſe, and may properly be ſtyled *liberall*, as juſtly deſerving the proſecution of an ingenuous minde. For if we conſider it according to its birth and originall, we ſhall finde it to ſpring from honourable parentage, being produced by *Geometry* on the one

one ſide, and *naturall Philoſophy* on the other. If according to its uſe and benefit, we may then diſcern that to this ſhould be referred all thoſe arts and profeſſions, ſo neceſſary for humane ſociety, whereby nature is not onely directed in her uſuall courſe, but ſometimes alſo commanded againſt her own law. The particulars that concern Architecture, Navigation, Husbandry, Military affairs, &c. are moſt of them reducible to this art, both for their invention and uſe.

Thoſe other diſciplines of Logick, Rhetorick, &c. doe not more protect and adorn the mind, then theſe Mechanicall powers doe the body.

And therefore are they well worthy to be entertained with greater induſtry and reſpect, then they commonly meet with in theſe times; wherein there be very many that pretend to be maſters in all the liberall arts, who ſcarce underſtand any thing in theſe particulars.

The ſubject of this art is concerning the heavineſſe of ſeverall bodies, or the proportion that is required betwixt any weight in relation to the power which may be able to move it. And ſo it refers likewiſe to violent and artificiall motion, as Philoſophy doth to that which is naturall.

The proper end for which this art is intended, is to teach how by underſtanding the true difference betwixt the *weight* and the *power*, a man may adde ſuch a fitting ſupplement to the ſtrength of the power, that it ſhall be able to move any conceivable weight, though it ſhould never ſo much exceed that force, which the power is naturally endowed with.

The art it ſelf may be thus deſcribed, to be a Mathematicall diſcipline, which by the help of Geometricall principles doth teach to contrive ſeverall weights and powers, unto any kind, either of motion or reſt, according as the Artificer ſhall determine.

If it be doubted how this may be eſteemed a *ſpecies* of Mathematicks, when as it treats of weights, and not of

Dav. Rivaltus præf. in lib. Archim. de centro gravitatis.

of quantity; For ſatisfaction to this, there are two particulars conſiderable.

1. *Mathematicks* in its latitude is uſually divided into *pure* and *mixed.* And though the *pure* doe handle only *abſtract quantity* in the *generall*, as *Geometry*, *Arithmetick* : yet that which is *mixed* doth conſider the quantity of ſome *particular determinate* ſubject. So *Aſtronomy* handles the quantity of heavenly motions, *Muſick* of ſounds, and *Mechanicks* of weights & powers.

2. Heavineſſe or weight is not here conſidered, as being ſuch a naturall *quality*, whereby condenſed bodies do of themſelves *tend downwards* ; but rather as being an affection, whereby they may be meaſured. And in this ſenſe *Ariſtotle* himſelfe referres it amongſt the other *ſpecies* of *quantity*, as having the ſame proper eſſence, which is to be compounded of integrall parts. So a pound doth conſiſt of ounces, drams, ſcruples. Whence it is evident, that there is not any ſuch repugnancy in the ſubject of this art, as may hinder it from being a true *ſpecies* of *Mathematicks*.

Metaph. l. 10. c. 2.

CAP.

Cap. III.

Of the first Mechanical faculty, the Ballance.

THe Mechanicall faculties, by which the experiments of this nature muſt be contrived, are uſually reckoned to be theſe ſix:

1. *Libra.*	1. *The Ballance.*
2. *Vectis.*	2. *The Leaver.*
3. *Axis in Peritrochio.*	3. *The Wheel.*
4. *Trochlea.*	4. *The Pulley.*
5. *Cuneus.*	5. *The Wedge.*
6. *Cochlea.*	6. *The Screw.*

Unto ſome of which, the force of all Mechanicall inventions muſt neceſſarily be reduced. I ſhall ſpeak of them ſeverally and in this order.

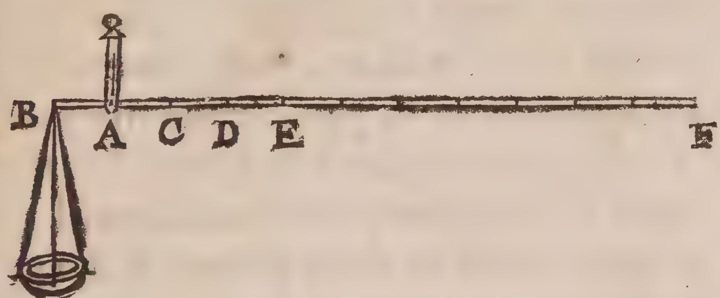
Firſt, concerning the Ballance; this, & the Leaver are uſually confounded together, as being but one faculty, becauſe the generall grounds & proportions of eithers force is ſo exactly the ſame. But for better diſtinctiõ, & more clear

clear discovery of their natures, I shall treat of them severally.

The first invention of the ballance is commonly attributed to *Astrea*, who is therefore deified for the goddesse of justice; and that instrument it self advanced amongst the celestiall signs.

The particulars concerning it are so commonly known, and of such easie experiment, that they will not need any large explication. The chief end and purpose of it, is for the distinction of severall ponderosities; For the understanding of which, we must note, that if the length of the sides in the Ballance, and the weights at the ends of them be both mutually equall, then the Beam will be in a horizontall situation. But on the contrary, if either the weights alone be equall, and not their distances, or the distances alone, and not the weights, then the Beam will accordingly decline.

As in this following diagram.



Suppoſe an equall weight at *C*, unto that at *B*, (which points are both equally diſtant from the center *A*,) it is evident that then the beam *B F*, will hang horizontally. But if the weight ſuppoſed at *C*, be unequall to that at *B*, or if there be an equall weight at *D E*, or any of the other unequall diſtances; the Beam muſt then neceſſarily decline.

With this kinde of Ballance, it is uſuall by the help onely of one weight, to meaſure ſundry different gravities, whether more or leſſe, then that by which they are meaſured. As by the example here deſcribed, a man may with one pound alone, weigh any other body within ten pounds, becauſe the heavineſſe of any weight doth *Cardan. Subtil.l.1.*

doth increaſe proportionably to its diſtance from the Center. Thus one pound at *D*, will equiponderate unto two pounds at *B*, becauſe the diſtance *A D*, is double unto *A B*. And for the ſame reaſon, one pound at *E*, will equiponderate to three pound at *B*, and one pound at *F*, unto ten at *B*, becauſe there is ſtill the ſame diſproportion betwixt their ſeverall diſtances.

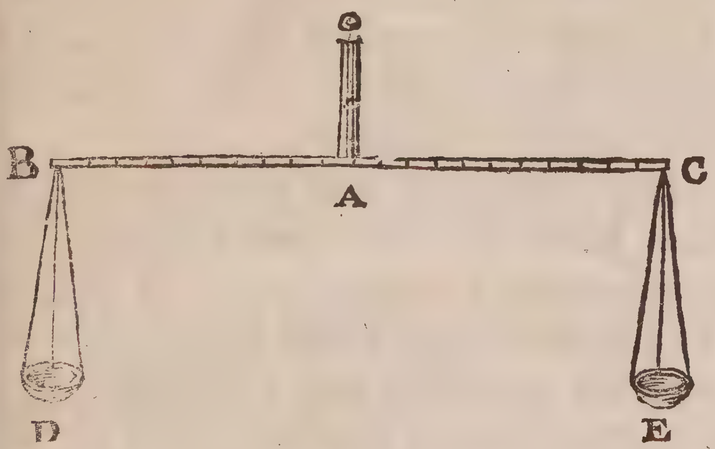
This kind of Ballance is uſually ſtyled *Romana*, *ſtatera*. It ſeems to be of ancient uſe, and is mentioned by *Ariſtotle* under the name of φάλαγξ. *Mechan. ca.21.*

Hence it is eaſie to apprehend, how that falſe ballance may be compoſed ſo often condemned by the wiſe man, as being an abomination to the Lord. If the ſides of the Beam be not equally divided, as ſuppoſe one have 10 parts, and the other 11, then any two weights that differ according to this proportion, (the heavier being placed on the ſhorter ſide, and the lighter on the longer) will equiponderate. And yet both the ſcoles being empty, ſhall hang in *æquilibrio*,

Prov.11.1 ca.16.11. Item, cap. 20.10.23.

Pappus. Collect. Mathem. l.8.

as if they were exactly just and true, as in this description.



Suppose *A C*, to have 11 such parts, whereof *A B*, has but 10, and yet both of them to be in themselves of equall weight; it is certain, that whether the scoles be empty, or whether in the scole *D*, we put 11 pound, and at *E*, 10 pound, yet both of them shall equiponderate, because there is just such a disproportion in the length of the sides *A C*, being unto *A B*, as 11 to 10.

The frequency of such cousenages in these days, may be evident from common experience: and that they were used also in former ages, may appear from *Aristotles* testimony concerning the Merchants in his time. For the remedying of such abuses the Ancients did appoint divers officers, styled ζυγοστάται, who were to overlook the common measures.

Quæstion. Mechan. c.2.
Budæus. Hence the proverb *Zygostatica fides.*

So great care was there amongst the Jews for the preservation of commutative justice from all abuse and falsification in this kind, that the publike standards and originals, by which all other measures were to be tryed and allowed, were with much religion preserved in the sanctuary, the care of them being committed to the Priests and Levites, whose office it was to look unto *all manner of measures and size.* Hence is that frequent expression, *According to the shekel of the Sanctuary*; and that Law, *All thy estimations shall bee according to the shekel of the Sanctuary*, which doth not refer to any weight or coin, distinct from, and more then the vulgar, (as some fondly conceive) but doth onely oblige men in their dealing and traffique to make use of such just

1 Chron. 23.29.
Exod.30. 13.
Lev.27.25

juſt measures, as were agreeable unto the publike ſtandards that were kept in the Sanctuary.

The manner how ſuch deceitfull ballances may be diſcovered, is by changing the weights into each other ſcole, and then the inequality will be manifeſt.

From the former grounds rightly apprehended, it is eaſie to conceive how a man may finde out the juſt proportion of a weight, which in any point given, ſhall equiponderate to ſeverall weights given, hanging in ſeverall places of the Beam.

Some of theſe ballances are made ſo exact, (thoſe eſpecially which the refiners uſe) as to be ſenſibly turned with the eightieth part of a grain: which (though it may ſeeme very ſtrange) is nothing to what * *Capellus* relates of one at *Sedan*, that would turne with the four hundredth part of a grain.

Maſter *Greaves* Romane foot.

* *De ponderibus & nummis l.1.*

There are ſeverall contrivances to make uſe of theſe in meaſuring the weight of blows, the force of powder, the ſtrength of ſtrings, or other oblong ſubſtances, condenſed air, the diſtinct proportion of ſeverall metals mixed together, the different gravity of divers bodies in the water, from what they have in the open air, with divers the like ingenuous inquiries.

CAP. IV.

Concerning the ſecond Mechanick faculty, the Leaver.

THe ſecond Mechanicall faculty, is the Leaver; the firſt invention of it is uſually aſcribed to *Neptune*, and repreſented by his Trident, which in the Greek are both called by one name, and are not very unlike in form, being both of them ſomewhat broader at one end, then in the other parts.

μόχλος.

Ariſtotle Quæſt. Mechan. cap. 4.

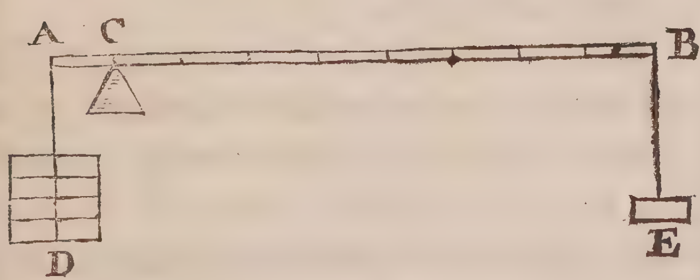
Archimedes, de Æquiponderant. l. 1. prop. 7.

Vitruvius Architect. l. 10. c. 8.

There is one main principle concerning it, which is (as it were) the very ſum and epitome of this whole art. The meaning of it is thus expreſſed by *Ariſtotle*, ὃ τὸ κινούμενον βάρος πρὸς τὸ κινοῦν, τὸ μῆκος πρὸς τὸ μῆκος ἀντιπέπονθεν. That

is,

is, as the weight is to an equivalent power, ſo is the diſtance betwixt the weight and the center, unto the diſtance betwixt the center and the power, and ſo reciprocally. Or thus, the power that doth equiponderate with any weight, muſt have the ſame proportion unto it, as there is betwixt their ſeverall diſtances from the center or fulciment: as in this following figure.



Where ſuppoſe the Leaver to bee repreſented by the length *A B*, the center or * prop at the point *C*, the weight to bee ſuſtained *D*, the power that doth uphold it *E*.

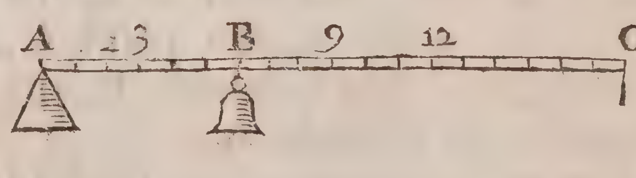
*This *Ariſtotle* cals ὑπομόχλιον. *Vitruvius*, *Preſſio*. *Vbaldus* *Fulcimentum*. *Dan. Barbarus*, *Scabellum*.

Now the meaning of the foreſaid principle doth import thus much; that the power at *E*, muſt bear the

 ſame

ſame proportion to the weight *D*, as the diſtance *C A*, doth to the other *C B*; which, becauſe it is octuple in the preſent example, therefore it will follow that one pound at *B*, or *E*, will equiponderate to eight pounds at *A*, or *D*, as is expreſſed in the figure. The ground of which maxime is this, becauſe the point *C*, is ſuppoſed to be the center of gravity, on either ſide of which, the parts are of equall weight.

And this kind of proportion is not onely to be obſerved when the power doth *preſſe downwards*, (as in the former example) but alſo in the other ſpecies of violent motion, as *lifting*, *drawing*, and the like. Thus if the prop or fulciment were ſuppoſed to be at the extremity of the Leaver,



As in this Diagram at *A*, then the weight *B*, would require ſuch a difference in the ſtrengths or powers that did ſuſtain it, as there is betwixt the ſeverall diſtances *A C*, and *B C*. For as the diſtance *A B*, is unto *A C*, ſo is the power at *C*, to the weight at *B*; that is, the power at *A*, muſt bee double to that at *C*, becauſe the diſtance *B C*, is twice as much as *B A*. From whence it is eaſie to conceive, how any burden carried betwixt two perſons, may be proportioned according to their different ſtrengths. If the weight were imagined to hang at the number 2, then the power at *C*, would ſuſtain but two of thoſe parts, whereof that at *A*, did uphold 16. If it be ſuppoſed at the figure (3) then the ſtrength at *C*, to that at *A*, would be but as three to fifteen. But if it were ſituated at the figure (9) then each of the extremities would participate of it alike, becauſe that being the middle, both the diſtances are equall. If at the number (12) then the ſtrength at *C*, is required to be

The right underſtanding of this doth much conduce to the explication of the Pulley.

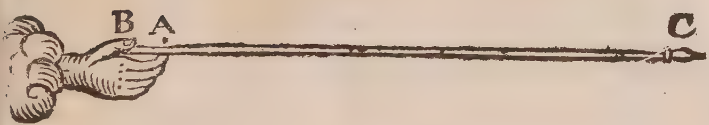
double unto that at *A*. And in the like manner are we to conceive of the other intermediate divisions.

Thus also must it be, if we suppose the power to be placed betwixt the fulciment and the weight, as in this example.

Where, as *A C*, is to *A B*, so is the power at *B*, to the weight at *C*.

Hence likewise may we conceive the reason why it is much harder to carry any long substance, either on the shoulders, or in the hand, if it be held by either of the extreams, then if it be sustained by the middle of it. The strength that must equiponderate at the nearer end, sometimes increasing the weight almost double to what it is in it self.

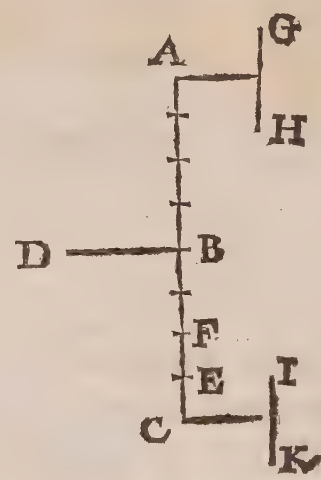
Imagine



Imagine the point *A*, to bee the place where any long ſubſtance (as ſuppoſe a Pike) is ſuſtained; it is evident from the former principle, that the ſtrength at *B*, (which makes it lye levell) muſt be equall to all the length *A C*, which is almoſt the whole Pike.

And as it is in the depreſſing, or elevating, ſo likewiſe is it in the drawing of any weight, as a Coach, Plow, or the like.

Let



Let the line *D B*, represent the Pole or Carriage on which the burden is ſuſtained, and the line *A C*, the croſſe barre; at each of its extremities, there is a ſeverall ſpring-tree *G H*, and *I K*, to which either horſes or oxen may be faſtned. Now becauſe *A*, and *C*, are equally diſtant from the middle *B*, therefore in this caſe the ſtrength muſt be equall on both ſides; but if we ſuppoſe one of theſe ſpring-trees to bee faſtned unto the points *E*, or *F*, then the ſtrength required to draw on that ſide, will be ſo much more, as the diſtance *E B*, or *F B*, is leſſe then that of *A B*; that is, either as three to four, as *E B*, to

B A,

B A, or as one to two, as *F B*, to *B A*. So that the beast fastned at *A*, will not draw so much by a quarter, as the other at *E*, and but half as much as one at *F*.

Whence it is easie to conceive how a husbandman (*cum inæquales veniunt ad aratra juvenci*) may proportion the labour of drawing according to the severall strength of his oxen.

Unto this Mechanicall faculty should bee reduced sundry other instruments in common use. Thus the oares, stearn, masts, &c. according to their force, whereby they give motion to the ship, are to be conceived under this head.

Arist. Mechan. c. 5, 6. 7. Vide Guevar. Comment.

Thus likewise for that engine, whereby Brewers and Dyers doe commonly draw water, which *Aristotle* cals κηλώνειον, and others *Tollenon*. This being the same kind of instrument, by which *Archimedes* drew up the ships of *Marcellus*.

Mechan. c. 29. Pet. Crinitus, de honesta Disciplina l. 19. c. 2. cals it corruptly *Tellenon*.

CAP.

CAP. V.

How the naturall motion of living creatures is conformable to these artificiall rules.

THe former principle being already explained, concerning artificiall and dead motions, it will not be altogether impertinent, if in the next place, wee apply it unto those that are naturall in living bodies, and examine whether these also are not governed by the same kinde of proportions.

In all perfect living creatures, there is a twofold kind of motive instruments:

1. Primary, the muscles.
2. Secondary, the members.

The muscles are naturally fitted to be instruments of motion, by the manner of their frame and composure; consisting of flesh as their chief materiall, and besides of Nervs, Ligatures, Veins, Arteries, and Membranes.

The *Nervs* ſerve for the convey-ance of the motive faculty from the brain. The *Ligatures* for the ſtrength-ning of them, that they may not flag and languiſh in their motions. The *Veins* for their nouriſhment. The *Ar-teries* for the ſupplying of them with ſpirit, and naturall vigor. The *Mem-branes* for the comprehenſion or in-cloſure of all theſe together, and for the diſtinction of one muſcle from another. There are beſides divers *fibræ* or hairy ſubſtances, which na-ture hath beſtowed for the farther corroborating of their motions; theſe being diſperſed through every muſcle, do ſo joyn together in the end of them, as to make intire nervous bo-dies, which are called *Tendones*, al-moſt like the griſles. Now this (ſaith *Galen*) may fitly be compared to the broader part of the Leaver, that is put under the weight, which, as it ought to be ſo much the ſtronger, by how much it is put to a greater force; ſo likewiſe by this, doth na-ture inable the muſcles and nervs for

De Placit. Hippoc. & Platon. l. 1. *ca.* 10.

for thoſe motions, which otherwiſe would be too difficult for them.

Whence it may evidently appear, that according to the opinion of that eminent Phyſitian, theſe naturall motions are regulated by the like grounds with the artificiall.

2. Thus alſo is it in thoſe ſecondary inſtruments of motion, the members: amongſt which, the hand is ὄργανον ὀργάνων, the inſtrument of inſtruments, (as *Galen* ſtyles it;) and as the ſoul of man doth bear in it the image of the divine wiſdome and providence, ſo this part of the body ſeems in ſome ſort to repreſent the omnipotency of God, whileſt it is able to perform ſuch various and wonderfull effects by the help of this art. But now for its own proper naturall ſtrength, in the lifting any great weight; this is always proportioned according to its extenſion from the body, being of leaſt force when it is fully ſtretched out, or at arms end, (as we ſay) becauſe then the ſhoulder joynt is as the center of

De uſu partiū l.1. c.2.

its

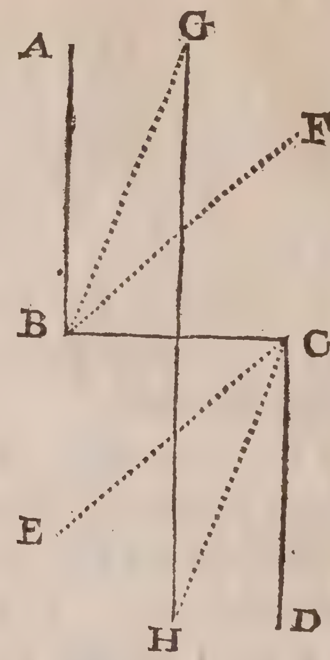
its motion, from which, the hand in that poſture, being very remote, the weight of any thing it holds muſt be accordingly augmented. Whereas the arm being drawn in, the elbow joynt doth then become its center, which will diminiſh the weight proportionably, as that part is neerer unto it then the other.

To this purpoſe alſo, there is another ſubtle probleme propoſed by *Ariſtotle*, concerning the poſtures of ſitting and riſing up. The quære is this, Why a man cannot riſe up from his ſeat, unleſſe he firſt, either bend his body forward, or thruſt his feet backward.

Mechan. c.31.

In the poſture of ſitting, our legs are ſuppoſed to make a right angle with our thighs, and they with our backs, as in this figure.

Where



Where let *A B*, represent the back, *B C*, the thighs, *C D*, the legs. Now it is evident, that a man cannot riſe from this poſture, unleſſe either the back *A B*, do firſt incline unto *F*, to make an acute angle with the thighs *B C*; or elſe that the legs *C D*, do incline towards *E*, which may alſo make an acute angle with the thighs *B C*; or laſtly, unleſſe both of them do decline to the points *G H*, where they may be included in the ſame perpendicular.

For

For the reſolution of which, the Philoſopher propoſes theſe two particulars.

1. A right angle (ſaith he) is a kind of equality, & that being naturally the cauſe of reſt, muſt needs be an impediment to the motion of riſing.

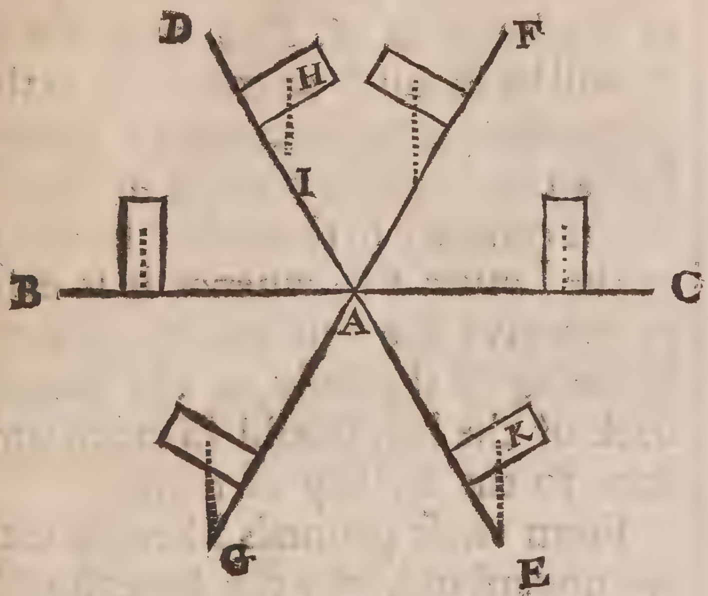
2. Becauſe when either of the parts are brought into an acute angle, the head being removed over the feet, or they under the head; in ſuch a poſture the whole man is much neerer diſpoſed to the form of ſtanding, wherein all theſe parts are in one ſtreight perpendicular line; then he is by the other of right angles, in which the back and legs are two parallels; or that of turning theſe ſtreight angles into obtuſe, which would not make an erect poſture but declining.

But neither of theſe particulars (as I conceive) doe fully ſatisfie the preſent quære, neither doe the Commentators, *Monantholius*, or *Guevara*, better reſolve it. Rather ſuppoſe *B C*, to be as a Vectis or Leaver, towards the middle of which is the place of the fulciment, *A B*, as the weight, *C D*, the power that is to raiſe it.

Now the body being ſituate in this rectangular forme, the weight *A B*, muſt needs be augmented proportionably to its diſtance from the fulciment, which is about halfe the thighs; whereas if we ſuppoſe either the weight to be inclined unto *F*, or the power to *E*, or both of them to *G H*, then there is nothing to bee lifted up but the bare weight it ſelf, which in this ſituation is not at all increaſed with any addition by diſtance.

For in theſe concluſions concerning the Leaver, we muſt always imagine that point which is touched by a perpendicular from the center of gravity, to be one of the tearms. So that the diverſe elevation or depreſſion of the inſtrument, will inferre a great alteration in the weight it ſelf, as may more clearly be diſcerned by this following Diagram.

Where



Where *A*, is ſuppoſed to be the place of the prop or fulciment, *B C*, a Leaver which ſtands horizontally, the power and the weight belonging unto it, being equall both in themſelves, and alſo in their diſtances from the prop.

But now ſuppoſe this inſtrument to be altered according to the ſituation *D E*, then the weight *D*, will be diminiſhed, by ſo much, as the perpendicular from its center of gravity *H I*, doth fall nearer to the prop or fulciment at *A*. And the power at *E*, will be so much augmented, as the perpendicular frõ its center (*K E*) does fall farther from the point at *A*. And so on the contrary in that other situation of the Leaver *F G*; whence it is easie to conceive the true reason, why the inclining of the body, or the putting back of the leg, should so much conduce to the facility of rising.

Sir *Fran: Bacons Nat. Hist. Exp.*731.

From these grounds likewise may we understand, why the knees should be most weary in ascending, and the thighs in descending, which is, because the weight of the body doth bear most upon the knee-joynts, in raising it self up, and most upon the muscles of the thighs when it stays it self in comming down.

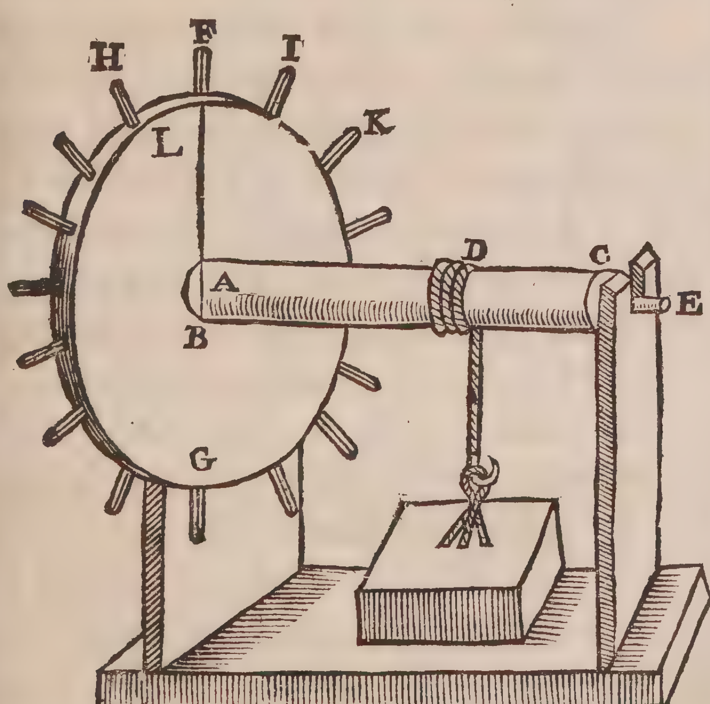
There are divers other naturall problemes to this purpose, which I forbear to recite. We doe not so much as goe, or sit, or rise, without the use of this Mechanicall Geometry.

CAP.

CAP. VI.
Concerning the Wheel.

THe third Mechanicall faculty is commonly ſtyled *axis in peritrochio.* It conſiſts of an axis or cylinder, having a rundle about it, wherein there are faſtned divers ſpokes, by which the whole may bee turned round; according to this figure.

Called likewiſe ὄνος. *Ariſt. Mechan.* c. 14.



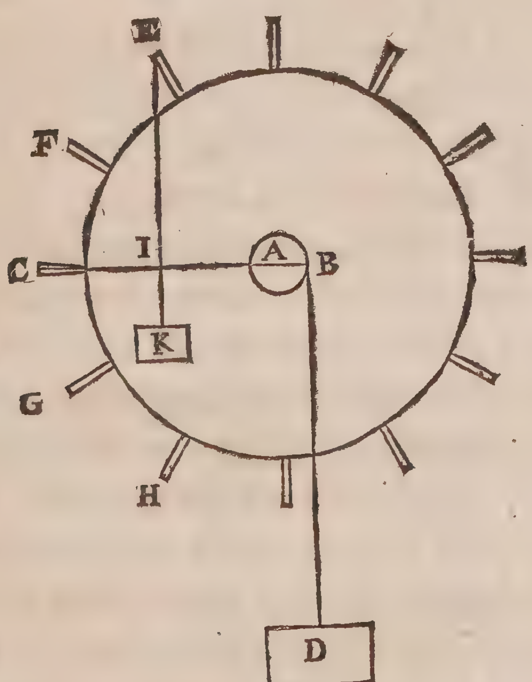
Where *B C*, does represent the Cylinder which is supposed to move upon a smaller Axis at *E*, (this being all one in comparison to the severall proportions, as if it were a meere Mathematicall line) *L G*, is the rundle or wheel, *H F I K*, severall spokes or handles that are fastned in it; *D*, the place where the cord is fastned for the drawing or lifting up of any weight.

The force of this instrument doth consist in that dis-proportion of distance, which there is betwixt the Semidiameter of the Cylinder *A B*, and the Semidiameter of the rundle with the spokes *F A*. For let us conceive the line *F B*, to be as a Leaver, wherein *A*, is the center or fulciment, *B*, the place of the weight, and *F*, of the power. Now it is evident from the former principles, that by how much the distance *F A*, is greater then *A B*, by so much lesse need the power be at *F*, in respect of the weight at *B*. Suppose *A B*, to be as the tenth part of *A F*, then that pow-

er

er or ſtrength, which is but as a hundred pound at *F*, will be equall to a thouſand pound at *B*.

For the clearer explication of this faculty, it will not be amiſſe to conſider the form of it, as it will appear being more fully expoſed to the view. As in this other Diagram.



Suppoſe *A B*, for the Semidiameter of the Axis or Cylinder, and *A C*, for the Semidiameter of the rundle, with the ſpokes; then the power at *C*, which will be able to ſupport the weight *D*, muſt bear the ſame proportion unto it, as *A B*, doth to *A C*: ſo that by how much ſhorter the diſtance *A B*, is in compariſon to the diſtance *A C*, by ſo much leſſe need the pow r be at *C*, which may be able to ſupport the weight *D*, hanging at *B*.

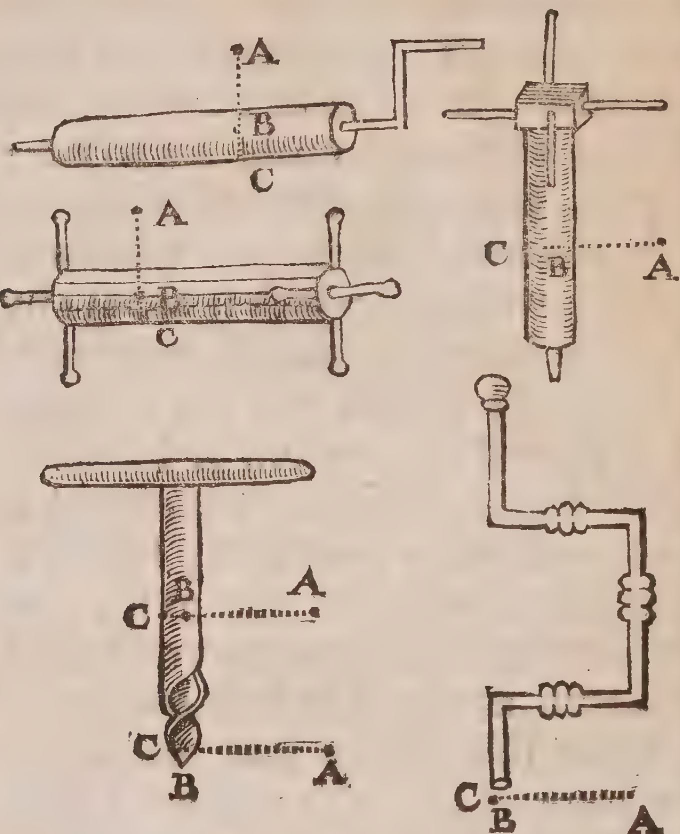
And ſo likewiſe is it for the other ſpokes or handles *E F G H*, at either of which, if we conceive any power, which ſhall move according to the ſame circumference wherin theſe handles are placed, then the ſtrength of this power will be all one, as if it were at *C*. But now ſuppoſing a dead weight hanging at any of them, (as at *E*,) then the diſproportion will vary. The power being ſo much leſſe then that at *C*, by how much the line *A C*, is longer then *A I*. The weight *K*, being of the ſame force at *E*, as if it were hung at *I*, in which point the perpendicular of its gravity doth cut the Diameter.

The chief advantage which this in-

instrument doth bestow, above that of the Leaver, doth consist in this particular. In a Leaver, the motion can bee continued onely for so short a space, as may be answerable to that little distance betwixt the fulciment and the weight: which is always by so much lesser, as the disproportion betwixt the weight and the power is greater, and the motion it self more easie: But now in this invention, that inconvenience is remedied; for by a frequent rotation of the axis, the weight may be moved for any height or length, as occasion shall require.

Unto this faculty may we referre the force of all those engines which consist of wheels with teeth in them.

Hence also may wee discerne the reason why sundry instruments in common use, are framed after the like form with these following figures.



All which are but ſeverall kinds of this third Mechanicall faculty. In which the points *A B C*, doe repreſent the places of the power, the fulciment, and the weight. The power being in the ſame proportion unto the weight, as *B C* is unto *B A*.

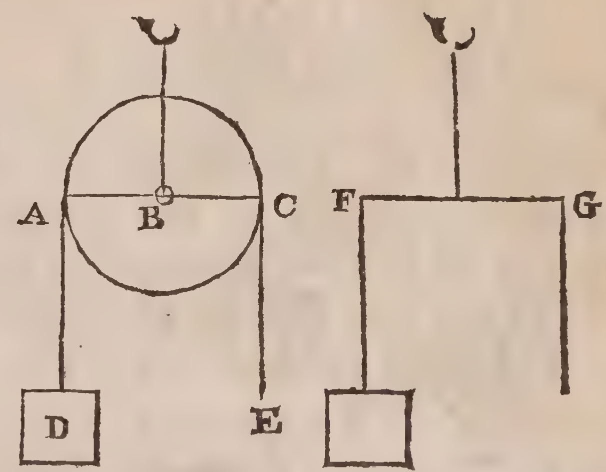
CAP.

Cap. VII.
Concerning the Pulley.

THat which is reckoned for the fourth faculty, is the Pulley: which is of ſuch ordinary uſe, that it needs not any particular deſcription. The chief parts of it are divers litle rundles, that are moveable about their proper axes. Theſe are uſually divided according to their ſeverall ſituations, into the upper and lower. If an engine have two of theſe rundles above, and two below, it is uſually called δίσπαστος, if three, τρίσπαστος, if many, πολύσπαστος. *Ariſt. Mechan. c. 19.*

The lower Pulleys onely doe give force to the motion. If we ſuppoſe a weight to hang upon any of the upper rundles, it will then require a power, that in it ſelfe ſhall be fully equall for the ſuſtaining of it.

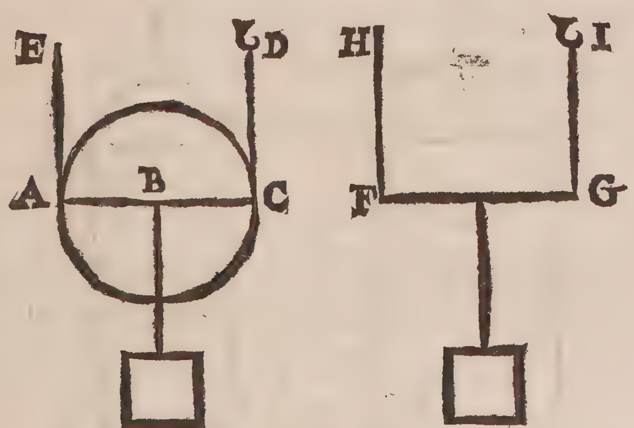
The



The Diameter *A C*, being as the beam of a ballance, of which *B* is the prop or center. Now the parts *A*, and *C*, being equally diſtant from this center, therefore the power at *E*, muſt be equall to the weight at *D*, it being all one as if the power and the weight were faſtned by two ſeverall ſtrings at the ends of the ballance *F G*.

Now all the upper Pulleys being of the ſame nature, it muſt neceſſarily follow, that none of them doe in themſelves conduce to the eaſing of the power, or lightning the weight, but onely for the greater conveniency of the motion, the cords by this means running more eaſily moved then otherwiſe they would.

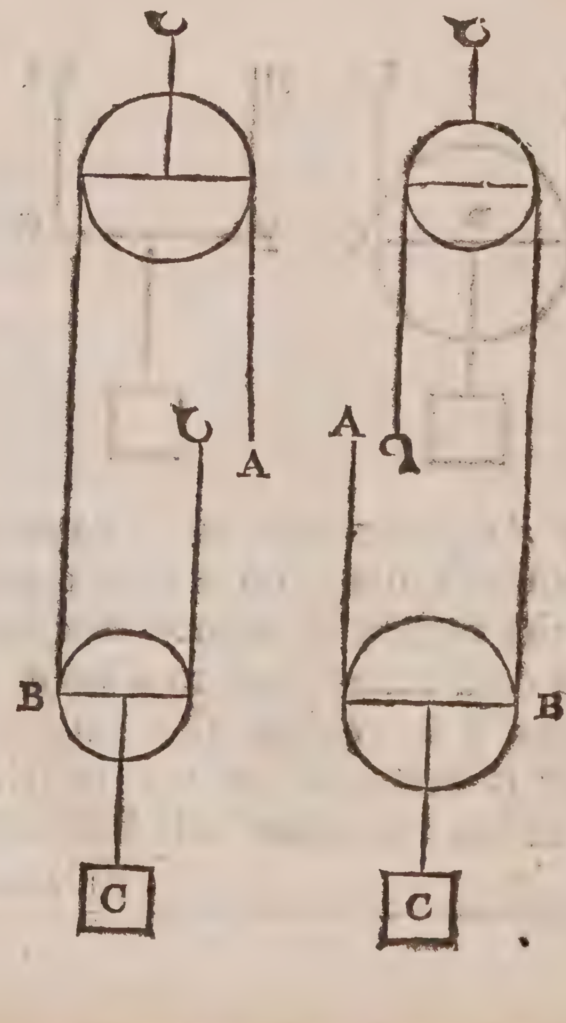
But now ſuppoſe the weight to be ſuſtained above the Pulley, as it is in all thoſe of the lower ſort: and then the power wch ſupports it, need be but half as much as the weight it ſelf.



Let *A C*, repreſent the Diameter of a lower Pulley, on whoſe center at *B*, the weight is faſtned, one end of the cord being tyed to a hook at *D*. Now it is evident, that halfe the weight is ſuſtained at *D*, ſo that there is but the other half left to be ſuſtained

ſuſtained by the power at *E*. It being all one as if the weight were tyed unto the middle of the ballance *F G*, whoſe ends were upheld by two ſeverall ſtrings, *F H*, and *G I*.

And this ſame ſubduple proportion will ſtill remain, though we ſuppoſe an upper Pulley joyned to the lower, as in theſe two other figures.



Where the power at *A*, is equall to the weight at *B*: Now the weight at *B*, being but half the ponderoſity *C*, therefore the power at *A*, notwithſtanding the addition of the upper rundle, muſt be equivalent to half the weight; and as the upper Pulley alone, doth not abate any thing of the weight, ſo neither being joyned with the lower, & the ſame ſubduple difference betwixt the power and the weight, which is cauſed by the lower Pulley alone, doth ſtill remain unaltered, though there be an upper Pulley added unto it.

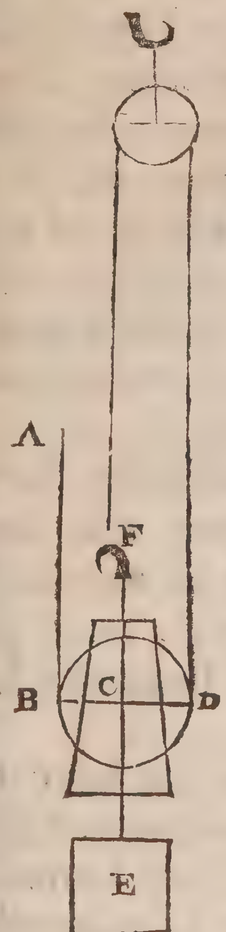
Now as one of theſe under Pulleys doth abate halfe of that heavineſſe which the weight hath in it ſelf, and cauſe the power to be in a ſubduple proportion unto it, ſo two of them doe abate halfe of that which remains, and cauſe a ſubquadruple proportion betwixt the weight and the power; three of them a ſubſextuple, four a ſuboctuple: and ſo for five, ſix, or as many as ſhall be required, they will all of them diminiſh the

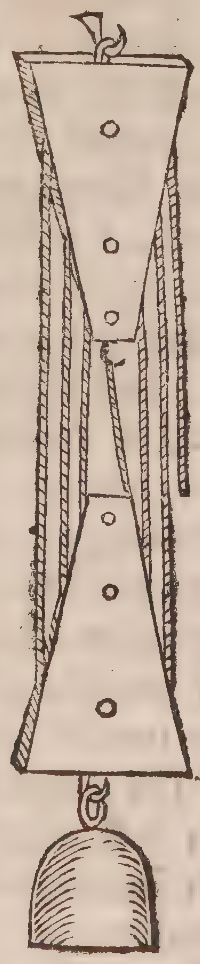
the weight according to this proportion.

Suppoſe the weight in it ſelf to be 1200 pound, the applying unto it one of theſe lowerPulleys,wil make it but as 600, two of them as 300, three of them as 150,&c.

But now, if we conceive the firſt part of the ſtring to be faſtned unto the lower Pulley, as in this other figure at *F*;

then





then the power at *A*, will be in a ſub-triple proportion to the weight *E*, becauſe the heavineſſe would be then equally divided unto the three points of the lower Diameter *B*, *C*, *D*, each of them ſupporting a like ſhare of the burden. If unto this lower Pulley there were added another, then the power would be unto the weight in a ſubquintuple proportion. If a third, a ſubſeptuple, and ſo of the reſt. For we muſt note, that the cords in this inſtrument are as ſo many powers, and the rundles as ſo many leavers, or ballances.

Hence it is eaſie to conceive, how the ſtrength of the power may bee proportioned according to any ſuch degree, as ſhall be required; and how any weight given, may be moved by any power given.

'Tis not materiall to the force of this inſtrument, whether the rundles of it be big or little, if they be made equall to one another in their ſeverall orders; But it is moſt convenient, that the upper ſhould each of them increaſe as they are higher, and the other as they are lower, becauſe by this means the cords will bee kept from tangling.

Theſe Pulleys may be multiplyed ac-

according to ſundry different ſituations, not onely when they are ſubordinate, as in the former examples, but alſo when they are placed collaterally.

From the former grounds it is eaſie to contrive a ladder, by which a man may pull himſelf up unto any height. For the performance of this, there is required onely an upper and a lower rundle:

To the uppermoſt of theſe at *A*, there ſhould be faſtned a ſharp graple or cramp of iron, which may be apt to take hold of any place where it lights. This part being firſt caſt up and faſtned, and the ſtaffe *D E*, at the nether end, being put betwixt the legs, ſo that a man may ſit upon the other *B C*, and take hold of the cord at *F*. it is evident that the weight of the perſon at *E*, will be but equall to half ſo much ſtrength at *F*; ſo that a man may eaſily pull himſelf up to the place required, by leaning but little more then half of his own weight on the ſtring *F*. Or if the Pulleys be multiplyed, this experiment may then be wrought with leſſe labour.

Cap. VIII.
Of the Wedge.

THe fift Mechanicall faculty is the Wedge, which is a known inſtrument, commonly uſed in the clea-

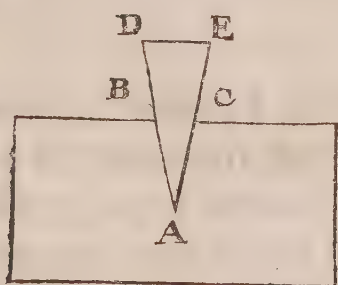
ving

ving of wood. The efficacy and great ſtrength of it may be reſolved unto theſe two particulars:

1. The form of it.

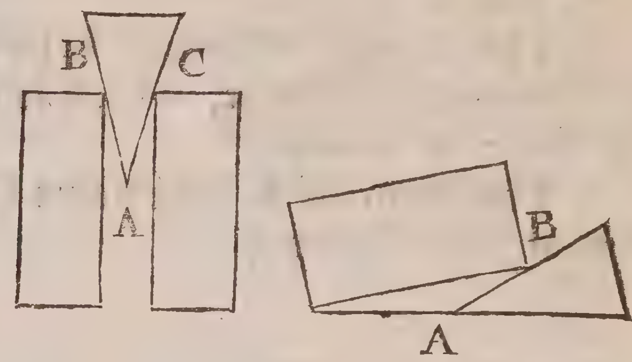
2. The manner whereby the power is impreſſed upon it, which is by the force of blows.

1. The form of it repreſents (as it were) two Leavers.



Each ſide *A D*, and *A E*, being one, the points *B C*, being in ſtead of ſeverall props or fulciments; the weight to be moved at *A*, and the power that ſhould move it, being applyed to the top *D E*, by the force of ſome ſtroake or blow: as *Ariſtotle* hath explained the ſeverall parts of this faculty. But now, becauſe this inſtrument may be ſo uſed that the *Mechan. c.*18.

point of it ſhall not touch the body to be moved, as in theſe other figures;



Therefore *Vbaldus* hath more exactly applyed the ſeverall parts of it according to this form, that the point *A*, ſhould be as the common fulciment, in which both the ſides doe meet, and (as it were) uphold one another; the points *B*, and *C*, repreſenting that part of the Leavers where the weight is placed.

It is a generall rule, that the more acute the angles of theſe wedges are, by ſo much more eaſie will their motion be; the force being more eaſily impreſſed, and the ſpace wherein the body is moved, being ſo much the leſſe. The

The ſecond particular whereby this faculty hath its force, is the *manner* whereby the power is impreſt upon it, which is by a ſtroak or blow; the efficacy of which doth much exceed any other ſtrength. For though we ſuppoſe a wedge being laid on a piece of timber, to be preſſed down with never ſo great a weight; nay though we ſhould apply unto it the power of thoſe other Mechanicall engines, the Pulley, Screw, &c. yet the effect would be ſcarce conſiderable in compariſon to that of a blow. The true reaſon of which, is one of the greateſt ſubtilties in nature, nor is it fully rendred by any of thoſe who have undertaken the reſolution of it. * *Ariſtotle*, *Cardan*, and *Scaliger*, doe generally aſcribe it unto the ſwiftneſſe of that motion; But there ſeems to be ſomething more in the matter then ſo; for otherwiſe it would follow that the quick ſtroak of a light hammer, ſhould be of greater efficacy, then any ſofter and more gentle ſtriking of a great

*Mechan. c. 10. Subtil. l. 17 Exercit. 331.

 ſledge.

ſledge. Or according to this, how ſhould it come to paſſe, that the force of an arrow or bullet diſcharged near at hand (when the impreſſion of that violence, whereby they are carried, is moſt freſh, and ſo in probability the motion at its ſwifteſt) is yet notwithſtanding much leſſe then it would be at a greater diſtance. There is therefore further conſiderable, the quality of that inſtrument by which this motion is given, and alſo the conveniency of diſtance through which it paſſes.

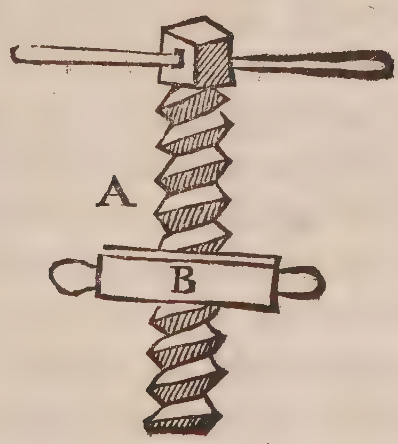
Unto this faculty is uſually reduced the force of files, ſaws, hatchets, &c. which are as it were but ſo many wedges faſtned unto a Vectis or Leaver.

Cap. IX.
Of the Screw.

THat which is uſually recited for the ſixth and laſt Mechanick faculty, is the Screw, which is deſcribed to be a kind of wedge that is multiplyed

plyed, or continued by a helicall revolution about a Cylinder, receiving its motion not from any ſtroak, but from a Vectis at one end of it. It is uſually diſtinguiſhed into two ſeverall kinds: the male, which is meant in the former deſcription, and the female, which is of a concave ſuperficies.

Pappus Collect. Mathemat.l.8.



The former is noted in the figure with the letter *A*, the other with *F*.

Ariſtotle himſelf doth not ſo much as mention this inſtrument, which yet notwithſtanding is of greater force and ſubtilty, then any of the reſt. It is chiefly applied to the ſqueezing or preſſing of things downewards,

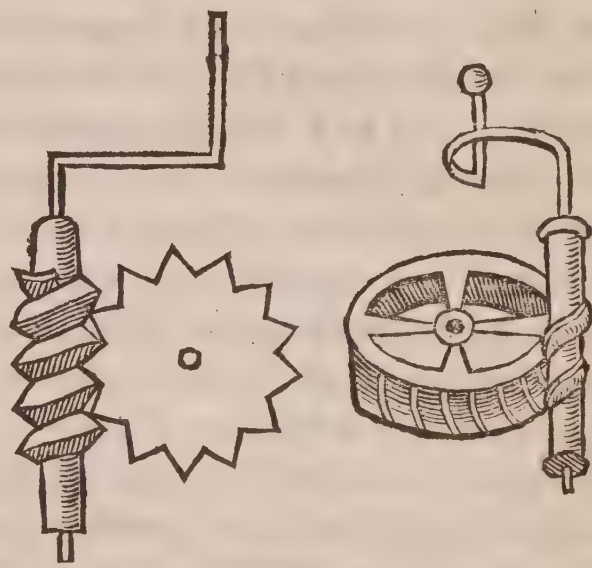
wards, as in the Preſſes for printing, for wine, oyl, and extracting the juice from other fruits. In the performance of which, the ſtrength of one man may bee of greater force, then the weight of a heavy mountain: It is likewiſe uſed for the elevating or lifting up of weights.

The advantage of this faculty above the reſt, doth mainly conſiſt in this: the other inſtruments doe require ſo much ſtrength for the ſupporting of the weight to be moved, as may be equall unto it, beſides that other ſuperadded power whereby it is out-weighed and moved; ſo that in the operations by theſe, a man does always ſpend himſelf in a continued labour.

Thus (for example) a weight that is lifted up by a Wheel or Pulley, will of it ſelf deſcend, if there bee not an equall power to ſuſtain it. But now in the compoſure of a Screw, this inconvenience is perfectly remedied; for ſo much force as is communicated unto this faculty, from the power that is applied unto it, is ſtill retained by the very frame and nature of the inſtrument it ſelf; ſince the motion of it cannot poſſibly return, but from the very ſame place where it firſt began. Whence it comes to paſſe, that any weight lifted up, with the aſſiſtance of this engine, may likewiſe be ſuſtained by it, without the help of any externall power, and cannot again deſcend unto its former place, unleſſe the handle of the Screw (where the motion firſt began) be turned back: ſo that all the ſtrength of the power, may be imployed in the motion of the weight, and none ſpent in the ſuſtaining of it.

The chief inconvenience of this inſtrument is, that in a ſhort ſpace it will be ſcrewed unto its full length, and then it cannot be of any further uſe for the continuance of the motion, nnleſſe it be returned back, and undone again as at the firſt. But this is uſually remedied by another invention, commonly ſtyled a *perpetuall*

tuall ſcrew, which hath the *motion* of a *wheel*, and the *force* of a *ſcrew*, being both infinite.



For the compoſure of which, inſtead of the female, or concave ſcrew, there muſt be a little wheel, with ſome notches in it, equivalent to teeth, by which the other may take hold of it, and turn it round, as in theſe other figures.

It is uſed in ſome Watches.

This latter engine does ſo far exceed all other contrivances to this purpoſe, that it may juſtly ſeem a wonder why it is not of as common uſe

uſe in theſe times and places,as any of the reſt.

Cap. X.

An enquiry into the magnificent works of the Ancients, which much exceeding our latter times, may ſeeme to inferre a decay in theſe Mechanicall Arts.

THus have I briefly treated concerning the generall principles of Mechanicks, together with the diſtinct proportions betwixt the weight and the power in each ſeverall faculty of it; Whence it is eaſie to conceive the truth and ground of thoſe famous ancient monuments, which ſeem almoſt incredible to theſe following ages. And becauſe many of them recorded by Antiquity, were of ſuch vaſt labour and magnificence, and ſo mightily diſproportionable to humane ſtrength, it ſhall not therefore be impertinent unto the purpoſe I aim at, for to ſpecifie ſome of of the most remarkable amongst them, and to inquire into the means and occasion upon which they were first attempted.

Amongst the *Ægyptians*, we read of divers Pyramids, of so vast a magnitude, as time it self in the space of so many hundred years hath not yet devoured. *Herodotus* mentions one of them, erected by *Cleopes* an Egyptian King, wherein there was not any one stone lesse then 30 foot long, all of them being fetched from *Arabia*. And not much after, the same Authour relates, how *Amasis* another Ægyptian, made himself a house of one entire stone, which was 21 cubits long, 14 broad, and 8 cubits high. The same *Amasis* is reported to have made the statue of a *Sphinx*, or Egyptian cat, all of one single stone, whose length was 143 foot, its height 62 foot, the compasse of this statues head containing 102 foot. In one of the Egyptian temples consecrated to *Jupiter*, there is related to be an Obelisk, consisting of 4 Smaragds or

Li.2.c.175

Plin.l.36. ca.12.

Plin.l.37. cap.5.

or Emeralds; the whole is 40 cubits high, 4 cubits broad at the bottome, and two at the top. *Sesostris* the King of Ægypt in a Temple at *Memphis*, dedicated to *Vulcan*, is reported to have erected two statues; one for himself, the other for his wife, both consisting of two severall stones, each of which were 30 cubits high.

Diodor. Sicul. Biblioth l.1. Sect.2.

Amongst the Jews we read in sacred Writ of *Solomons* Temple, which for its state and magnificence, might have been justly reckoned amongst the other wonders of the world, wherein besides the great riches of the materials, there were works too of as great labour. Pillars of brasse 18 cubits high, and 12 cubits round, great and costly stones for the foundation of it. *Josephus* tels us that some of them were 40 cubits, others 45 cubits long. And in the same chapter he mentions the three famous Towres built by *Herod*, wherein every stone being of white marble, was 20 cubits long, 10 broad, and 5 high. And which was the greatest won-

1 Kings 7. 15. cap.5.v.17

De bello Iuda.l.6. c.6.

wonder, the old wall it ſelf was ſituated on a ſteep riſing ground, and yet the hils upon it, on the tops of wch theſe Towers were placed, were about 30 cubits high, that 'tis ſcarce imaginable by what ſtrength ſo many ſtones of ſuch great magnitude ſhould be conveyed to ſo high a place.

Plin.l.36. c.14. Panciroll. Deperd. Tit.32.

Amongſt the Grecians we read of the *Epheſian* Temple dedicated to *Diana*, wherein there were 127 columnes made of ſo many ſeverall ſtones, each of them 60 foot high, being all taken out of the quarries in *Aſia*. 'Tis ſtoried alſo of the brazen *Coloſſus*, or great ſtatue in the Iſland of *Rhodes*, that it was 70 cubits high. The thumbs of it being ſo big that no man could graſp one of them about with both his arms; when it ſtood upright, a ſhip might have paſſed betwixt the legs of it, with all its ſails fully diſplayed; being thrown down by an earth-quake, the braſſe of it did load 900 Camels. But above all ancient deſigns to this purpoſe, that would have been moſt wonder-

Plin.l.34. c.3.

wonderfull, which a Grecian Architect did propound unto *Alexander*, to cut the mountain *Athos* into the forme of a ſtatue, which in his right hand ſhould hold a Town capable of ten thouſand men, and in his left a Veſſell to receive all the water that flowed from the ſeverall ſprings in the mountain. But whether *Alexander* in his ambition did feare that ſuch an Idoll ſhould have more honour then he himſelf, or whether in his good husbandry, hee thought that ſuch a *Microcoſme* (if I may ſo ſtyle it) would have coſt him almoſt as much as the conquering of this great world, or what ever elſe was the reaſon, he refuſed to attempt it.

Vitruv. Archit. l. 2.

Amongſt the *Romanes* we read of a brazen *Coloſſus*, made at the command and charges of *Nero*, which was 120 foot high; *Martiall* cals it *Sydereus*, or ſtarry.

Suet. Ner.

Hic ubi Sydereus propius videt aſtra Coloſſus. And it is ſtoried of *M. Curio*, that he erected two *Theaters* ſufficiently

Pancirol. Deperd. Tit. 18.

ently capacious of people, contrived moveable upon certain hinges; Sometimes there were ſeverall playes and ſhows in each of thē, neither being any diſturbance to the other; & ſometimes they were both turned about, with the people in them, and the ends meeting together, did make a perfect *Amphitheater*: ſo that the ſpectators which were in either of them, might joyntly behold the ſame ſpectacles.

*IdēTit.*31. There were beſides at *Rome* ſundry *Obelisks*, made of ſo many intire ſtones, ſome of them 40, ſome 80, and others 90 cubits high. The chief of them were brought out of Ægypt, where they were dug out of divers quarries, & being wrought into form, were afterwards (not without incredible labour, and infinite charges) conveyed unto *Rome*. In the year 1586, there was erected an old *Obelisk*, which had been formerly dedicated unto the memory of *Julius Cæſar*. It was one ſolid ſtone, being an Ophite or kind of ſpotted Marble. The height of it was 107 foot, the breadth of it

at

at the bottome was 12 foot, at the top 8. Its whole weight is reckoned to be 956148 pounds, beſides the heavineſſe of all thoſe inſtruments that were uſed about it, which (as it is thought) could not amount to leſſe then 1042824 pounds. It was tranſplaced at the charges of Pope *Sixtus* the fifth, from the left ſide of the *Vatican*, unto a more eminent place about a hundred foot off, where now it ſtands. The moving of this *Obelisk* is celebrated by the writings of above 56 ſeverall Authours, (ſaith *Monantholius*) all of them mentioning it, not without much wonder and praiſe. Now if it ſeem ſo ſtrange and glorious an attempt to move this *Obelisk* for ſo little a ſpace, what then may we think of the carriage of it out of Ægypt, and divers other far greater works performed by Antiquity? This may ſeem to infer, that theſe Mechanicall arts are now loſt, and decayed amongſt the many other ruines of time: which yet notwithſtanding cannot be granted, without much ingrati-

Comment. in Mechan. Ariſt. c. 19.

tude to thoſe learned men, whoſe labours in this kind we enjoy, and may juſtly boaſt of. And therefore for our better underſtanding of theſe particulars, it will not be amiſſe to enquire both *why*, and *how*, ſuch works ſhould be performed in thoſe former and ruder ages, which *are not*, and (as it ſhould ſeem) *cannot* be effected in theſe later and more learned times. In the examination of which, wee ſhall finde that it is not the want of art that diſables us for them, ſince theſe Mechanicall diſcoveries are altogether as perfect, and (I think) much more exact now, then they were heretofore; but it is, becauſe we have not either the ſame *motives*, to attempt ſuch works, or the ſame *means* to effect them as the Ancients had.

CAP.

Cap. XI.
That the Ancients had divers motives *and* means *for ſuch vaſt magnificent works, which we have not.*

THe *motives* by which they were excited to ſuch magnificent attempts, we may conceive to be chiefly three:

Religion.
Policy.
Ambition.

1. *Religion.* Hence was it that moſt of theſe ſtately buildings were intended for ſome ſacred uſe, being either Temples or * Tombes, all of them dedicated to ſome of their Deities. It was an in-bred principle in thoſe ancient Heathen, that they could not chuſe but merit very much by being liberall in their outward ſervices. And therefore we read of *Crœſus*, that being overcome in a battell, and taken by *Cyrus*, he did revile the gods of ingratitude, because they had no better care of him, who had ſo frequently adored

* As Pyramids, Obelisks.

Herodot. l. 1.

adored them with costly oblations. And as they did conceive themselves bound to part with their lives in defence of their religion: so likewise to employ their utmost power and estate, about any such design, which might promote or advance it. Whereas now, the generality of men, especially the wisest sort amongst them, are in this respect of another opinion, counting such great and immense labours, to be at the best but glorious vanities. The Temple of *Solomon* indeed was to be a type, and therefore it was necessary that it should be so extraordinarily magnificent, otherwise perhaps a much cheaper structure might have been as commendable and serviceable.

2. *Policy*, that by this means they might find out imployment for the people, who of themselves being not much civilized, might by idlenesse quickly grow to such a rudenesse and barbarisme, as not to be bounded within any laws of governmẽt. Again, by this means the riches of the kingdome

Plin.l.6. c.12.

dome did not lye idly in their kings treaſuries, but was always in motion, which could not but be a great advantage, and improvement to the Common-wealth. And perhaps ſome of them feared leſt if they ſhould leave too much money unto their ſucceſſors, it might be an occaſion to inſnare them in ſuch idle and vain courſes, as would ruine their kingdomes. Whereas in theſe later ages, none of all theſe politick incitements can be of any force, becauſe now there is imployment enough for all, and mony little enough for every one.

3. *Ambition* to be known unto poſterity; and hence likewiſe aroſe that incredible labour and care they beſtowed, to leave ſuch monuments behinde them, as might * *continue for ever*, and make them famous unto all after ages. This was the reaſon of *Abſalons* pillar, ſpoken of in Scripture, *to keep his name in remembrance.* And doubtleſſe this too was the end which many other of the Ancients have aimed at, in thoſe (as they thought)

* Pſal.49. 11.

2 Sam.18. 18.

thought) everlasting buildings.

But now these later ages are much more active and stirring: so that every ambitious man may finde so much businesse for the present, that he shall scarce have any leisure to trouble himself about the future. And therefore in all these respects, there is a great disproportion betwixt the incitements of those former and these later times unto such magnificent attempts.

Again, as they differ much in their *motives* unto them, so likewise in the meanes of effecting them.

There was formerly more leisure and opportunity, both for the great men to undertake such works, and for the people to perfect them. Those past ages were more quiet and peaceable, the Princes rather wanting imployment, then being over-prest with it, and therefore were willing to make choice of such great designs, about which to busie themselves: whereas now the world is growne more politick, and therefore more trouble-

troublesome, every great man having other private and necessary businesse about which to imploy both his time and means. And so likewise for the common people, who then living more wildly without being confined to particular trades and professions, might be more easily collected about such famous imployments; whereas now, if a Prince have any occasion for an Army, it is very hard for him to raise so great a multitude, as were usually imployed about these magnificent buildings. We read of 360000 men that were busied for twenty years in making one of the Ægyptian Pyramids. And *Herodotus* tels us of 1000000 men who were as long in building another of them. About the carriage of one stone for *Amasis* the distance of twenty days journy, there was for three years together imployed 2000 chosen men, Governours, besides many other under-labourers. 'Twas the opinion of * *Josephus* and *Nazienzen*, that these Pyramids were built by *Joseph* for granaries against the years

*Lib.*2.

* *Antiq.l.*2. *c.*5.

years of famine. Others think that the brick made by the children of *Iſrael*, was imployed about the framing of them, becauſe we read that the Tower of *Babel* did conſiſt of brick or artificiall ſtone, *Gen.* 11. 3. And if theſe were the labourers that were buſied about them, 'tis no wonder though they were of ſo vaſt a magnitude; for we read that the children of *Iſrael* at their comming out of Ægypt, were numbred to be ſix hundred thouſand, and three thouſand, and five hundred and fifty men, *Numb.* 1. 46. ſo many handfuls of earth would almoſt make a mountain, and therefore wee may eaſily beleeve that ſo great a multitude in ſo long a ſpace as their bondage laſted, for above four hundred years, might well enough accompliſh ſuch vaſt deſigns.

In the building of *Solomons* Temple, there were threeſcore and ten thouſand that bare burdens, and fourſcore thouſand hewers in the mountains, 1 *Kings* 5.15.

The *Epheſian* Temple was built by all

all *Asia* joyning together, the 127 pillars were made by ſo many kings, according to their ſeverall ſucceſſions, the whole work being not finiſhed under the ſpace of two hundred and fifteen years. Whereas the tranſplacing of that Obelisk at *Rome* by *Sixtus* the fift, (ſpoken of before) was done in ſome few days by five or ſix hundred men; and as the work was much leſſe then many other recorded by Antiquity: ſo the means by which it was wrought, was yet far leſſe in this reſpect then what is related of them.

2. The abundance of wealth, which was then ingroſſed in the poſſeſſion of ſome few particular perſōs, being now diffuſed amongſt a far greater number. There is now a greater equality amongſt mankind, and the flouriſhing of arts and ſciences, hath ſo ſtirred up the ſparks of mens naturall nobility, and made them of ſuch active and induſtrious ſpirits, as to free themſelves in a great meaſure from that ſlavery, which thoſe former and wilder

wilder Nations were ſubjected unto.

In building one of the Pyramids, there was expended for the maintenance of the labourers, with Radiſh and Onyons, no leſſe then eighteen hundred talents, which is reckoned to amount unto 1880000 crowns, or thereabouts. And conſidering the cheapneſſe of theſe things in thoſe times and places, ſo much money might go farther then a ſumme ten times greater could doe in the maintenance of ſo many now.

In *Solomons* Temple we know how the extraordinary riches of that King, the generall flouriſhing of the whole State, and the liberality of the people did joyntly concur to the building of the Temple. *Pecuniarum copia & populi largitas, majora dictu conabatur,* (ſaith *Joſephus.*) The *Rhodian* Coloſſus is reported to have coſt three hundred talents the making. And ſo were all thoſe other famous monuments of proportionable expence.

De bell. Iud. l. 6. ca. 6.

Pancirollus ſpeaking of thoſe Theaters that were erected at the charges

of

of ſome private Romane Citizens, ſaith thus: *Noſtro hoc ſæculo vel Rex ſatis haberet quod ageret ædificio ejuſmodi erigendo*; and a little after upon the like occaſion, *Res mehercule miraculoſa, quæ noſtris temporibus vix à potentiſsimo aliquo rege poſsit exhiberi.* *Deperd. Tit.18.*

3. Adde unto the two former conſiderations that exact *care* and indefatigable *induſtry* which they beſtowed in the raiſing of thoſe ſtructures: Theſe being the chief and only deſigns on which many of them did imploy all their beſt thoughts and utmoſt endevours. *Cleopes* an Ægyptian King is reported to have been ſo deſirous to finiſh one of the Pyramids, that having ſpent all about it he was worth, or could poſſibly procure, he was forced at laſt to proſtitute his own daughter for neceſſary maintenance. And we read of *Ramiſes* another King of Ægypt, how that he was ſo careful to erect an Obelisk, about wch he had imployed 20000 men, that when he feared leſt through the negligence of the artificers, or weakneſſe of the engine, *Plin.l.36. c.9.*

gine, the ſtone might fall and break, he tyed his own ſon to the top of it, that ſo the care of his ſafety might make the workmen more circumſpect in their buſineſſe. And what ſtrange matters may be effected by the meer diligence and labour of great multitudes, we may eaſily diſcern from the wilde Indians, who having not the art or advantage of Engines, did yet by their unwearied induſtry remove ſtones of an incredible greatneſſe. *Acoſta* relates that he himſelf meaſured one at *Tiaguanaco*, which was thirty eight foot long, eighteen broad, and ſix thick, and he affirms that in their ſtatelieſt ædifices, there were many other of much vaſter magnitude.

Hiſtor. Ind. l.6.c.14.

From all which conſiderations it may appear, that the ſtrangeneſſe of thoſe ancient monuments above any that are now effected, does not neceſſarily infer any defect of art in theſe later ages. And I conceive, it were as eaſie to demonſtrate the Mechanicall Arts in theſe times to be ſo farre beyond the knowledge of former

ages,

ages, that had we but the ſame means as the Ancien's had, we might effect far greater matters then any they attempted, and that too in a ſhorter ſpace, and with leſſe labour.

CAP. XII.

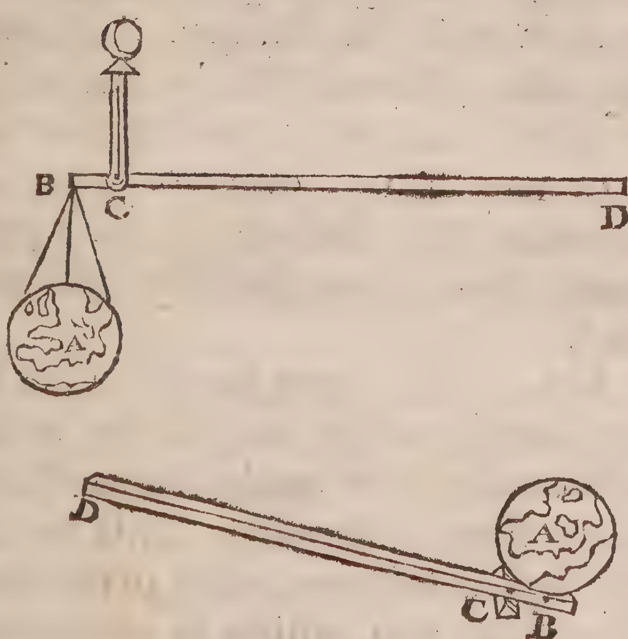
Concerning the force of the Mechanick faculties, particularly the Ballance and Leaver. How they may be contrived to move the whole world, or any other conceivable weight.

ALL theſe magnificent works of the Ancients before ſpecified, are ſcarce conſiderable in reſpect of art, if we compare them with the famous ſpeeches and acts of *Archimedes*: Of whom it is reported that he was frequently wont to ſay, how that he could move, *Datum pondus cum datâ potentiâ*, The greateſt conceivable weight with the leaſt conceivable power: and that if he did but know where to ſtand and faſten his inſtrument, he could move the world, all this great globe of ſea and land; which *promiſes*, though they were altogether above the vulgar apprehenſion or belief, yet becauſe his *acts* were ſomewhat anſwerable thereunto, therefore the King of *Syracuſe* did enact a law whereby every man was bound to beleeve, what ever *Archimedes* would affirm.

'Tis eaſie to demonſtrate the Geometricall truth of thoſe ſtrange aſſertions, by examining them according to each of the forenamed *Mechanick* faculties, every one of which is of infinite power.

To begin with the two firſt of them, the Ballance and the Leaver, (which I here joyn together, becauſe the proportions of both are wholly alike) 'tis certain, though there ſhould bee the greateſt imaginable weight, and the leaſt imaginable power, (ſuppoſe the whole world, & the ſtrength of one man or infant) yet if we conceive the ſame diſ-proportion betwixt their ſeverall diſtances in the former faculties from the ſulciment or center of gravity,

vity, they would both equiponde. rate. And if the diſtance of the power from the center, in compariſon to the diſtance of the weight, were but any thing more then the heavineſſe of the weight is in reſpect of the power, it may then be evident from the former principles, that the power would be of greater force then the weight, and conſequently able to move it.



Thus if we ſuppoſe this great globe at *A*, to cōtain 2400000000000000000000000 pounds,allowing a hundred pound for each cubicall foot in it, (as *Stevinius* hath calculated) yet a man or childe at *D*, whose strength perhaps is but equivalent to one hundred, or tenne pounds weight, may be able to out-weigh and move it, if there be but a little greater disproportion betwixt the two distances *C D*, and *C B*, then there is betwixt the heavinesse of the weight, and the strength of the power, that is, if the distance *C D*, unto the other distance *C B*, be any thing more thē 2400000000000000000000000 unto 100 or 10, every ordinary instrument doth include all these parts *really*, though not sensibly distinguished.

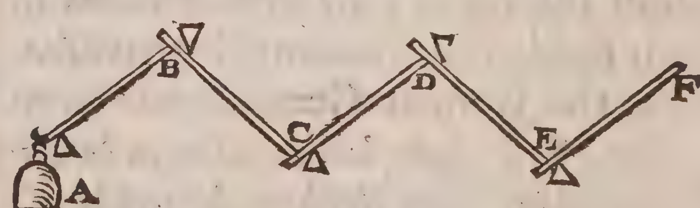
Static. l.3. prop 10.

Under this latter faculty I did before mention that engine by which *Archemedes* drew up the Roman ships, at the siege of *Syracuse*. This is usually styled *Tollenon*, being of the same form with that which is commonly used by Brewers, and Dyers, for the drawing of water. It consists of two posts

Lipsius Poliorcet. l.1. Dialog.6.

poſts, the one faſtned perpendicularly in the ground, the other being jointed on croſſe to the top of it. At the end he faſtned a ſtrong hook or grapple of iron, which being let over the wall to the river, he would thereby take hold of the ſhips, as they paſſed under; and afterwards by applying ſome weight, or perhaps the force of Screwes to the other end, hee would thereby lift them into the open air, where having ſwinged them up and down till he had ſhaked out the men and goods that were in them, he would then daſh the Veſſels againſt the rocks, or drown them in their ſudden fall: inſomuch that *Marcellus* the Roman Generall was wont to ſay, ταῖς μὲν ναυσὶν αὐτοῦ κυαθίζειν ἐκ θαλάττης Ἀρχιμήδην, That *Archimedes* made uſe of his ſhips in ſtead of Buckets, to draw water with. *Plutach.* in his life.

This faculty will be of the ſame force, not only when it is continued in one, but alſo when it is multiplied in divers inſtruments, as may be conceived in this other form, which I doe not mention, as if it could be ſerviceable for any motion (ſince the ſpace by which the weight would be moved, will be ſo little as not to fall under ſenſe) but only for the better explication of this Mechanick principle , and for the right underſtanding of that force ariſing from multiplication in the other faculties, which doe all depend upon this. The Wheel, and Pulley , and Screw, being but as ſo many Leavers of a circular form and motion, whoſe ſtrength may therefore be continued to a greater ſpace.



Imagine the weight *A*, to be a hundred thouſand pounds , and the diſtance of that point, wherein every Leaver touches either the weight or one another from the point where they touch the prop , to be but one

ſuch

ſuch part; whereof the remainder contains ten, then according to the former grounds 10000 at *B*, will equiponderate to *A*, which is 100000; ſo that the ſecond Leaver hath but 10000 pounds to move. Now becauſe this obſerves the ſame proportions with the other in the diſtances of its ſeverall points, therefore 1000 pounds at *C*, will be of equall weight to the former. And the weight at *C*, being but as a thouſand pound, that which is but as a hundred at *D*, will be anſwerable unto it; and ſo ſtill in the ſame proportion, that which is but 10 at *E*, will be equall to 100 at *D*; and that which is but one pound at *F*, will alſo be equall to ten at *E*. Whence it is manifeſt, that 1 pound at *F*, is equall to 100000 at *A*; and the weight muſt always be diminiſhed in the ſame proportion as ten to one, becauſe in the multiplication of theſe Leavers, the diſtance of the point, where the inſtrument touches the weight, from that where it touches the prop, is but as one ſuch part, whereof the remainder contains ten. But now if wee imagine it to be as the thousandth part, then must the weight be diminished according to this proportion; and then in the same multiplication of leavers, 1 l. will be equall to 1000 000 000 000 000 pounds: so that though we suppose the weight to be never so heavy, yet let the disproportion of distances be greater, or the Leavers more, and any little power may move it.

CAP. XIII.

Of the Wheel, by multiplication of which it is easie to move any imaginable weight.

THe Wheel or *axis in peritrochio*, was before demonstrated to bee of equivalent force with the former faculties. If we conceive the same difference betwixt the Semidiameter of the wheels or spokes *A C*, and the Semidiameter of the axis *A B*, as there is betwixt the weight of the world, and

See the figure cap. 6. pa. 38.

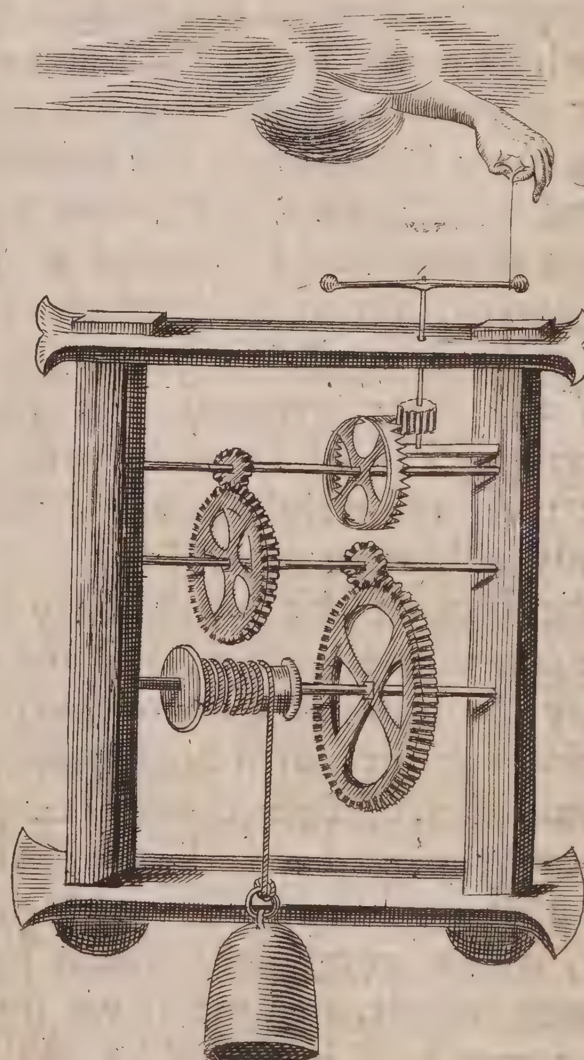
and the ſtrength of a man, it may then be evident, that this ſtrength of one man, by the help of ſuch an inſtrument, will equiponderate to the weight of the whole world. And if the Semidiameter of the wheel *AC*, be but any thing more in reſpect of the Semidiameter of the axis *AB*, then the weight of the world ſuppoſed at *D*, is in compariſon to the ſtrength of a man at *C*; it may then be manifeſt from the ſame grounds that this ſtrength will be of ſo much greater force then the weight, and conſequently able to move it.

An engine of many wheels is is commonly called *Gloſſocomus.*

The force of this faculty may be more conveniently underſtood and uſed by the multiplication of ſeverall wheels, together with nuts belonging unto each of them; as it may be eaſily experimented in the ordinary Jacks that are uſed for the roaſting of meat, which commonly conſiſt but of three wheels, and yet if we ſuppoſe a man tyed in the place of the weight, it were eaſie by a ſingle hair faſtned unto the fly or ballance of the

How to pull a man above ground with a ſingle hair.

Jack, to draw him up from the ground, as will be evident from this following figure.



Where ſuppoſe the length of the fly or ballance in compariſon to the breadth of its axis, to be as 10 to one, and ſo for the three other wheels in reſpect of the nuts that belong unto thẽ; (though this difference be oftentimes leſſe, as we may well allow it to be) withall ſuppoſe the weight (or a man tyed in the place of it) to be a hundred pounds: I ſay according to this ſuppoſition, it is evident that the power at the ballance, which ſhall be equall to the weight, need be but as 1 to 10000. For the firſt axis is conceived to be but as the tenth part of its wheel, and therefore though the weight in it ſelf be as 10000, yet unto a power that hath this advantage, it is but as 1000, and therefore this thouſand unto the like power at the ſecond wheel, will be but as 100, and this 100 at the third but as 10; and laſtly, this ten at the ballance but as one. But the weight was before ſuppoſed to be 100, which to the firſt wheel will be but 10, to the ſecond as one, to the third as a deci-

mall,

mall, or one tenth, to the ſails as one hundreth part: ſo that if the hair be but ſtrong enough to lift $\frac{1}{10000}$ that is, one ten thouſandth part of a man, or (which is all one) one hundreth part of a pound, it may as well ſerve by the help of this inſtrument for the drawing of him up. And though there be not altogether ſo great a diſproportion betwixt the ſeverall parts of a Jack, (as in many perhaps there is not;) and though a man may be heavier then is here ſuppoſed, yet 'tis withall conſiderable that the ſtrength of a hair is able to bear much more then the hundreth part of a pound.

Comment. in Gen.c.1. v.10, art.6 De viribus motricibus Theor.16.

Upon this ground *Merſennus* tels us out of *Solomon de Cavet*, that if there were an engine of 12 wheels, each of them with teeth, as alſo the axes or nuts that belong unto them, if the Diameter of theſe wheels were unto each *axis*, as a hundred to one: and if we ſuppoſe theſe wheels to be ſo placed, that the teeth of the one might take hold of the axis that belongs unto the next, and that the axis

of

of the handle may turn the firſt wheel, and the weight be tyed unto the axis of the laſt, with ſuch an engine as this, ſaith he, a child (if he could ſtand any where without this earth) might with much eaſe move it towards him.

For according to the former ſuppoſition, that this globe of ſea and land, did contain as many hundred pounds, as it doth cubicall feet, *viz.* 24000000000000000000000000, it may be evident that any ſtrength, whoſe force is but equivalent to 3 pounds, will by ſuch an engine bee able to move it.

Of this kinde was that engine ſo highly extolled by *Stevinus*, which he cals *Pancration*, or *Omnipotent*, preferring it before the inventions of *Archimedes*. It conſiſted of wheeles and nuts, as that before ſpecified is ſuppoſed. Hither alſo ſhould be referred the force of racks, which ſerve for bending of the ſtrongeſt bows, as alſo that little pocket engine wherewith a man may break or wrench open

De Staticæ praxi.

Ramelli Fig. 160.

pen any dore, together with divers the like instruments in common use.

CAP. XIV.

Concerning the infinite strength of Wheels, Pulleys, & Screws. That it is possible by the multiplication of these, to pull up any Oak by the roots with a hair, lift it up with a straw, or blow it up with ones breath, or to perform the greatest labour with the least power.

FRom what hath been before delivered concerning the nature of the Pulley, it is easie to understand, how this faculty also may be proportioned betwixt any weight, and any power, as being likewise of infinite strength.

'Tis reported of *Archimedes*, that with an engine of Pulleys, to which he applyed onely his left hand, he lifted up * 5000 bushels of corn at once, and drew a ship with all its lading

* 7000 saith *Zetzes Chiliad.* 2. *Hist.* 35.

ding upon dry land. This engine *Zetzes* cals *Trispatum*, or *Trispastum*, which signifies only a threefold Pulley; But herein he doth evidently mistake, for 'tis not possible that this alone should serve for the motion of so great a weight, because such an engine can but make a subsextuple, or at most a subseptuple proportion betwixt the weight and power, which is much too little, to reconcile the strength of a man unto so much heavinesse. Therefore *Vbaldus* doth more properly style it *Polyspaston*, or an instrument of many Pulleys: How many, were easie to find out, if we did exactly know the weight of those ancient measures; supposing them to be the same with our bushell in *England*, which contains 64 pintes or pounds, the whole would amount to 320000 pounds, half of which would be lightned by the help of one Pulley, three quarters by two Pulleys, and so onward, according to this subduple, subquadruple, and subsextuple proportion: So that if we conceive the strength of

Præf. ad Mechan.

of the left hand to be equivalent unto 20 or 40 pounds, it is easie to finde out how many Pulleys are required to inable it for the motion of so great a weight.

Comment. in Gen.c.1. v.10.art.6.

Upon this ground *Mersennus* tels us, that any little childe with an engine of an hundred double Pulleys, might easily move this great globe of earth, though it were much heavier then it is. And in reference to this kind of engine (saith *Monantholius*) are we to understand that assertion of *Archimedes*, (as he more immediately intended it) concerning the possibility of moving the world.

Præf. ad Mechan. Aristotle.

The wedge was before demonstrated to be as a double Vectis or Leaver, and therefore it would be needlesse to explain particularly how this likewise may be contrived of infinite force.

The Screw is capable of multiplication, as well as any of the other faculties, and may perhaps be more serviceable for such great weights, then any of the rest. *Archimedes* his engine

engine of greateſt ſtrength, called *Chariſtion*, is by ſome thought to conſiſt of theſe. *Axes habebat cum infinitis cochleis.* And that other engine of his called *Helix* (mentioned by * *Athenæus*) wherewith he lifted *Hiero's* great ſhip into the ſea, without any other help, is moſt likely to be framed of perpetuall ſcrews, ſaith *Rivaltus*.)

Stevin. de Static. prax. See *Beſſon.*

* *Deipnoſophiſt. li. 5. Oper. exter. Archimed.*

Whence it may evidently appear, that each of theſe Mechanick faculties are of infinite power, and may be contrived proportionable unto any conceivable weight. And that no naturall ſtrength is any way comparable unto theſe artificiall inventions.

'Tis reported of *Sampſon*, that he he could carry the gates of a city upon his ſhoulders, and that the ſtrongeſt bonds were unto him but as flax burnt with fire, and yet his hair being ſhaved off, all his ſtrength departed from him. We * read of *Milo*, that he could carry an Oxe upon his back, and yet when he tried to tear an Oak aſunder

Judg. 15.

* *A. Gell. Noct. Att. l. 15. c. 16.*

der

der that was ſomewhat riven before, having drawn it to its utmoſt, it ſuddenly joined together again, catching his hands in the cleft, and ſo ſtrongly manackled him, that he became a prey to the wilde beaſts.

But now by theſe Mechanicall contrivances, it were eaſie to have made one of *Sampſons* hairs that was ſhaved off, to have been of more ſtrength, then all of them when they were on. By the help of theſe arts it is poſſible (as I ſhall demonſtrate) for any man to lift up the greateſt Oak by the roots with a ſtraw, to pull it up with a hair, or to blow it up with his breath.

Suppoſe the roots of an Oak to extend a thouſand foot ſquare, (which is almoſt a quarter of a mile) and forty foot deep, each cubicall foot being a hundred pound weight; which though it be much beyond the extēſion of any tree, or the weight of earth, the compaſſe of the roots in the ground (according to common opinion) not extending further then the branches of it in the air, and the depth of it not above ten foot, beyond which the greateſt rain doth not penetrate (ſaith * Seneca.) *Ego vinearum diligens foſſor affirmo nullam pluviam eſſe tam magnam, quæ terram ultra decem pedes in altitudinem madefaciat.* And becauſe the root muſt receive its nouriſhment from the help of ſhowers, therefore it is probable that it doth not goe below them. So that (I ſay) though the proportions ſuppoſed doe much exceed the reall truth, yet it is conſiderable that ſome great overplus muſt be allowed for that labour which there will be in the forcible divulſion or ſeparation of the parts of the earth which are continued.

* *Nat. Qu. l. 3. c. 7.*

According to this ſuppoſition, the work of forcing up the Oak by the roots, will be equivalent to the lifting up of 4000000000 pound weight, which by the advantage of ſuch an engine, as is here deſcribed, may be eaſily performed with the leaſt conceivable power.

The whole force of this engine doth confist in two double Pulleys, twelve wheels, and a fail. One of thefe Pulleys at the bottome will diminifh half of the weight, fo that it fhall be but as 2000000000, and the other Pulley will abate ¾ three quarters of it: fo that it fhall be but as 1000000000. And becaufe the beginning of the ftring being faftned unto the lower Pulley, makes the power to be in a fubquintuple proportion unto the weight, therefore a power that fhall be as 1000000000, that is, a fubquadruple, will be fo much ftronger then the weight, and confequently able to move it. Now fuppofe the breadth of all the axes and nuts, to be unto the Diameters of the wheel as ten to one; and it will then be evident, that to a power at the firft wheel, the weight is but as 100000000. To the fecond as 10000000. To the third as 1000000. To the fourth as 100000. To the fifth as 10000. To the fixth as 1000. To the feventh as 100. To the eighth See cha.7.

 as

as 10. To the ninth as 1. To the tenth as $\frac{1}{10}$, one decimall. To the eleventh as $\frac{1}{100}$. To the twelfth as $\frac{1}{1000}$. And to the ſails yet leſſe. So that if the ſtrength of the ſtraw, or hair, or breath, be but equall to the weight of one thouſandth part of a pound, it may be of ſufficient force to pull up the Oak.

If in this engine we ſuppoſe the diſproportion betwixt the wheeles and nuts, to be as a hundred to one, then it is very evident that the ſame ſtrength of breath, or a hair, or a ſtraw, would be able to move the whole world, as will be eaſily found by calculation. Let this great globe of ſea and land bee imagined (as before) to weigh ſo many hundred pounds as it contains cubicall feet; namely, 2400000000000000000000000 pounds. This will bee to the firſt Pulley, 1200000000000000000000000. To the ſecond leſſe thẽ 600000000000000000000000. But for more eaſie and convenient reckoning, let it be ſuppoſed to be ſomewhat more, *viz.* 1000000000000000000000000

This

This to the firſt wheel will be but as 10000000000000000000000.

To the ſecond as	100000000000000000000.
To the third as	1000000000000000000.
To the fourth as	10000000000000000.
To the fifth	100000000000000.
To the ſixth	1000000000000.
To the ſeventh	10000000000.
To the eighth	100000000.
To the ninth	1000000.
To the tenth	10000.
To the eleventh	100.
To the twelfth	1.
To the ſails as	$\frac{1}{100}$.

So that a power which is much leſſe then the hundredth part of a pound will bee able to move the world.

It were needleſſe to ſet down any particular explication, how ſuch Mechanicall ſtrength may be applyed unto all the kinds of locall motion; ſince this, in it ſelf is ſo facill and obvious, that every ordinary artificer doth ſufficiently underſtand it.

The ſpecies of locall violent motion are by *Ariſtotle* reckoned to bee theſe four:

Phys.l.7. c.3.

Pulsio.
Tractio.
Vectio.
Vertigo.

Thrusting, Drawing, Carrying, Turning. Unto some of which all these artificiall operations must necessarily be reduced, the strength of any power being equally applyable unto all of them; So that there is no work impossible to these contrivances, but there may be as much acted by this art, as can be fancied by imagination.

CAP. XV.

Concerning the proportion of slownesse and swiftnesse in Mechanicall motions.

HAving already discoursed concerning the *strength* of these Mechanicall faculties: it remains for the more perfect discovery of their natures, that we treat somewhat concerning those two differences of artificiall motion:

Slow-

Slownesse,
and
Swiftnesse.

Without the right understanding of which, a man shall be exposed to many absurd mistakes, in attempting of those things, which are either in themselves impossible, or else not to be performed with such means as are applyed unto them. I may safely affirm, that many, if not most mistakes in these Mechanicall designs, doe arise from a mis-apprehension of that difference, which there will be betwixt the slownesse or swiftnesse of the weight and power, in comparison to the proportion of their severall strengths.

Hence it is, that so many engines invented for mines and water-works doe so often fail in the performance of that for which they were intended, because the artificers many times doe forget to allow so much time for the working of their engine, as may be proportionable to the difference betwixt the weight and power that belong unto them: whereas he that rightly underſtands the grounds of this art, may as eaſily find out the difference of ſpace and time, required to the motion of the weight and power, as he may their different ſtrengths; and not only tell how any power may move any weight, but alſo in what a ſpace of *time* it may move it any ſpace or *diſtance*.

If it were poſſible to contrive ſuch an invention, whereby any conceivable weight may be moved by any conceivable power, both with the ſame quickneſſe and ſpeed (as it is in thoſe things which are immediately ſtirred by the hand, without the help of any other inſtrument) the works of nature would be then too much ſubjected to the power of art: and men might be thereby incouraged (with the builders of *Babell*, or the rebell Gyants) to ſuch bold deſignes as would not become a created being. And therefore the wiſdome of providence hath ſo confined theſe humane arts, that what any invention

hath

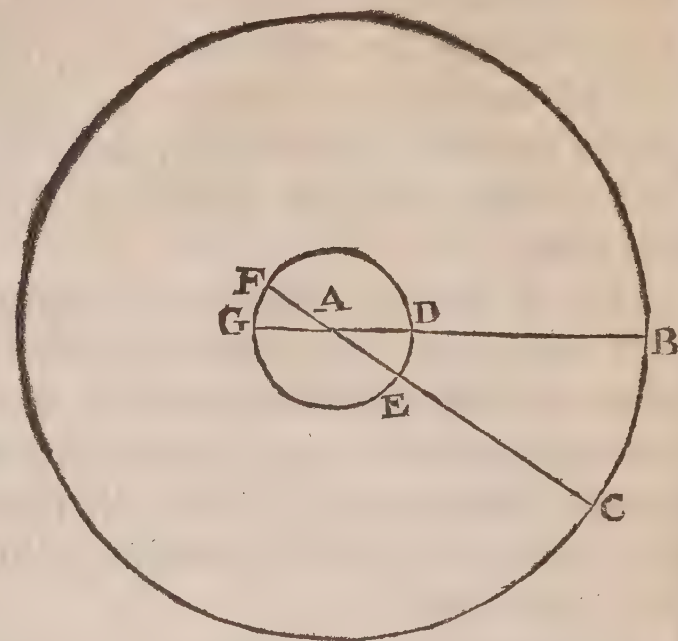
hath in the *ſtrength* of its motion, is abated in the *ſlowneß* of it: and what it hath in the extraordinary *quickneß* of its motion, muſt be allowed for in the great *ſtrength* that is required unto it.

For it is to be obſerved as a generall rule, that the ſpace of time or place, in which the weight is moved, in compariſon to that, in which the power doth move, is in the ſame proportion as they themſelves are unto one another.

So that if there be any great difference betwixt the ſtrength of the weight and the power, the ſame kind of differences will there be in the ſpaces of their motion.

To illuſtrate this by an example:

Let



Let the line *G A B*, represent a ballance or leaver, the weight being supposed at the point *G*, the fulciment at *A*, and the power sustaining the weight at *B*. Suppose the point *G*, unto which the weight is fastned, to be elevated unto *F*, and the opposite point *B*, to be depressed unto *C*; 'tis evident that the arch *F G*, or (which is all one) *D E*, doth shew the space of the weight, and the arch *B C*, the motion of the power. Now both

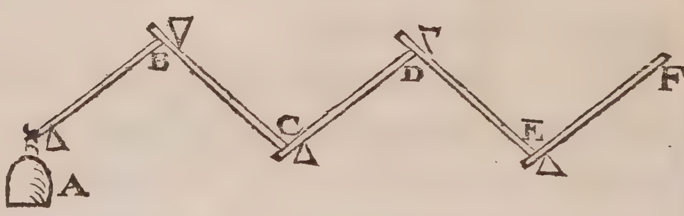
both theſe arches have the ſame proportion unto one another, as there is betwixt the weight and the power, or (which is all one) as there is betwixt their ſeverall diſtances from the fulciment. Suppoſe *A G*, unto *A B*, to be as one unto four, it may then be evident that *F G*, or *D E*, will be in the ſame proportion unto *B C*. For as any two Semidiameters are unto one another, ſo are the ſeverall circumferences deſcribed by them, as alſo any proportionall parts of the ſame circumferences.

And as the weight and power doe thus differ in the ſpaces of their motions, ſo likewiſe in the ſlowneſſe of it; the one moving the whole diſtance *B C*, in the ſame time, wherein the other paſſes onely *G F*. So that the motion of the power from *B* to *C*, is four times ſwifter then that of the weight from *G* to *F*. And thus will it be, if we ſuppoſe the diſproportions to be far greater, whether or no we conceive it, either by a *continuation* of the ſame inſtrument and

fa-

faculty, as in the former example, or by a *multiplication* of divers, as in Pulleys, Wheels, &c. By how much the power is in it ſelfe leſſe then the weight, by ſo much will the motion of the weight be ſlower, then that of the power.

To this purpoſe I ſhall briefly touch at one of the Diagrams expreſſed before in the twelfth Chapter, concerning the multiplication of Leavers.



In which, as each inſtrument doth diminiſh the weight according to a decuple proportion, ſo alſo doe they diminiſh the *ſpace* and *ſlowneſſe* of its motion. For if we ſhould conceive the firſt Leaver *B*, to be depreſſed unto its loweſt, ſuppoſe ten foot, yet the weight *A*, would not be raiſed

ſed above one foot; but now the ſecond Leaver at its utmoſt could move but a tenth part of the firſt, and the third Leaver but a tenth part of the ſecond, and ſo of the reſt. So that the laſt Leaver *F*, being depreſſed, will paſſe a *ſpace* 100000 greater, and by a motion, 100000 ſwifter then the weight at *A*.

Thus are we to conceive of all the other faculties, wherein there is conſtantly the ſame diſproportiō betwixt the weight and power, in reſpect of the ſpaces and ſlowneſſe of their motions, as there is betwixt their ſeverall gravities. If the power be unto the weight, but as one unto a hundred, then the ſpace through which the weight moves, will be a hundred times leſſe, and conſequently the motion of the weight a hundred times ſlower then that of the power.

So that it is but a vain and impoſſible fancy for any one to think that he can move a great weight with a litle power in a litle ſpace; but in all theſe Mechanicall attempts, that advantage which is gotten in the ſtrength of the motion, muſt be ſtill allowed for in the ſlowneſſe of it.

Though theſe contrivances doe ſo extreamly increaſe the power, yet they doe proportionably protract the time. That which by ſuch helps one man may doe in a hundred days, may be done by the immediate ſtrength of a hundred men in one day.

Cap. XVI.

That it is poſſible to contrive ſuch an artificiall motion, as ſhall bee of a ſlowneſſe proportionable to the ſwiftneſſe of the heavens.

IT were a pretty ſubtilty to inquire after, whether or no it be not poſſible to contrive ſuch an artificiall motion, that ſhould be in ſuch a proportion ſlow, as the heavens are ſuppoſed to be ſwift.

For the exact reſolution of which, it would be requiſite that we ſhould firſt pitch upon ſome *medium*, or indiffedifferent motion , by the diſtance from which, we may judge of the proportions on either ſide, whether ſlowneſſe or ſwiftneſſe. Now becauſe there is not any ſuch *naturall medium*, which may be abſolutely ſtyled an indifferent motion, but that the ſwiftneſſe and ſlowneſſe of every thing, is ſtill proportioned either to the quantity of bodies, in which they are, or ſome other particular end for which they are deſigned; therefore we muſt take liberty to ſuppoſe ſuch a motion, and this we may conceive to be about 1000 paces, or a mile in an hower.

The ſtarry heaven, or 8th ſphere is thought to move 42398437 miles in the ſame ſpace: So that if it may be demonſtrated that it is poſſible to contrive ſuch a motion, which going on in a conſtant direct courſe, ſhall paſſe but the 42398437 part of a mile in an hower, it will then be evident, that an artificiall motion may bee ſlow, in the ſame proportion as the heavens are ſwift.

Now

Now it was before manifested that according to the difference betwixt the weight and power, so will the difference be betwixt the slownesse or swiftnesse of their motions; whence it will follow, that in such an engine, wherein the weight shall bee 42398437 pounds, and the power that doth equiponderate it, but the 42398437 part of a pound (which is easie to contrive) in this engine the power being supposed to move with such a swiftnesse, as may be answerable to a mile an hower, the weight will passe but the 42398437 part of a mile in the same space, and so consequently will be proportionably slow unto the swiftnesse of the heavens.

Preface to *Euclid.*

It is related by our Country-man *I. Dee*, that he and *Cardan* being both together in their travels, they did see an instrument which was at first sold for 20 talents of gold, wherein there was one wheel, which constantly moving round amongst the rest, did not finish one revolution under the space of seven thousand years.

But

But if we farther confider fuch an inftrument of wheels as was mentioned before in the 14 chapter, with which the whole world might bee eafily moved, we fhall then find that the motion of the weight by that, muft be much more flow, then the heavens are fwift. For though wee fuppofe (faith *Stevinus*) the handle of fuch an engine with 12 wheels to be turned about 4000 times in an hower, (which is as often as a mans pulfe doth beat) yet in ten years fpace the weight by this would not be moved above $\frac{10512}{24000000000000000000}$ parts of one foot, which is nothing near fo much as a hairs breadth. And it could not paffe an inch in 1000000 years, faith *Merfennus*. *De ftat. pract.* *Phænom. Mechan prop. 11.*

The truth of which we may more eafily conceive, if we confider the frame and manner of this 12 wheeld engine. Suppofe that in each axis or nut, there were ten teeth, and on each wheel a thoufand: then the fails of this engine muft be turned a hundred times, before the firft wheel, (reckoning

ning downward) could bee moved round once, and ten thouſand times before the ſecond wheel can finiſh one revolution, and ſo through the 12 wheels,according to this multiply-ed proportion.

So that beſides the wonder wch there is in the force of theſeMechanical motions, the extream ſlowneſſe of them is no leſſe admirable. If a man conſider that a body ſhould remaine in ſuch a conſtant direct motion, that there could not bee one minute of time, wherein it did not rid ſome ſpace, and paſſe on further, and yet that this body in many years together, ſhould not move ſo far as a hairs breadth.

Which notwithſtanding may evidently appear from the former inſtance. For ſince it is a naturall principle, that there can be no penetration of bodies, and ſince it is ſuppoſed, that each of the parts in this engine doe touch one another in their ſuperficies, therefore it muſt neceſſarily follow, that the weight does begin and

and continue to move with the power: and (however it is insensible) yet it is certain there must be such a motion so extreamly slow, as is here specified. So full is this art of rare and incredible subtilties.

I know it is the assertion of *Cardan*, *Motus valde tardi, necessario quietes habent intermedias.* Extream slow motions have necessarily some intermediate stops and rests: But this is onely said, not proved, and he speaks it from sensible experiments, which in this case are fallible. Our senses being very incompetent judges of the severall proportions, whether greatnesse or littlenesse, slownesse or swiftnesse, which there may bee amongst things in nature. For ought we know, there may be some *Organicall* bodies, as much lesse then ours, as the earth is bigger. We see what strange discoveries of extream minute bodies, (as lice, wheal-worms, mites, and the like) are made by the *Microscope*, wherein their severall parts (which are altogether invisible to the

De varietate rerum l.9.c.47.

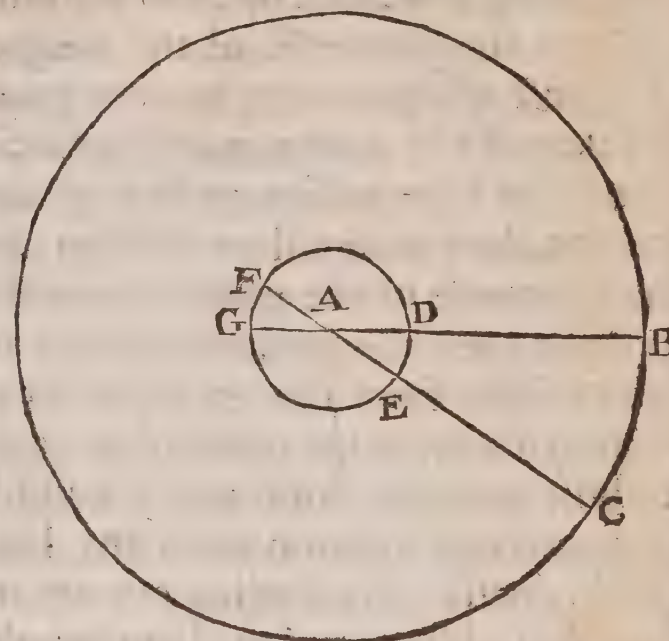
bare eye) will diſtinctly appear: and perhaps there may be other inſects that live upon them as they doe upon us. 'Tis certain that our ſenſes are extreamly diſproportioned for comprehending the whole compaſſe and latitude of things. And becauſe there may be ſuch difference in the *motion* as vvell as in the *magnitude* of bodies; therefore, though ſuch extream ſlowneſſe may ſeem altogether impoſſible to ſenſe and common apprehenſion, yet this can be no ſufficient argument againſt the reality of it.

Cap. XVII.

Of ſwiftneſſe: how it may be increaſed to any kind of proportion. Concerning the great force of Archimedes *his Engines. Of the Balliſta.*

BY that which hath been already explained concerning the ſlowneſs of motion, we may the better underſtand the nature of ſwiftneſſe, both of them (as is the nature of oppoſites

ſites) being produced by contrary cauſes. As the greatneſſe of the weight in reſpect of the power, and the great diſtance of the power from the fulciment, in compariſon to that of the weight, does cauſe a ſlow motion: So the greatneſſe of the power above the vveight, and the greater diſtance of the vveight from the center, in compariſon to that of the power does cauſe a ſwift motion. And as it is poſſible to contrive a motion unto any kind of ſlowneſſe, by finding out an anſwerable diſproportion betwixt the weight and power: ſo likewiſe unto any kind of ſwiftneſſe. For ſo much as the weight does exceed the power, by ſo much will the motion of the weight be ſlower, and ſo much as the power does exceed the weight, by ſo much vvill the motion of the weight be ſwifter.



In the Diagram ſet down before, if we ſuppoſe *F*, to be the place of the power, and *C* of the weight, the point *A*, being the fulciment or center, then in the ſame ſpace of time, vvherein the power does move from *F*, to *G*, the weight will paſſe from *C*, to *B*. Theſe diſtances having the ſame diſproportion unto one another, as there is betwixt *A F*, and *A C*, which is ſuppoſed to be quadruple. So that in this example, the weight vvill move four

four times ſwifter then the power. And according as the power does exceed the vveight in any greater diſproportion, ſo will the ſwiftneſſe of the weight be augmented.

Hence may vve conceive the reaſon of that great force vvhich there is in Slings, vvhich have ſo much a greater ſwiftneſſe, then a ſtone thrown from the hand, by how much the end of the Sling is farther off from the ſhoulder-joynt, vvhich is the center of motion. The ſacred hiſtory concerning *Davids* victory over *Goliah*, may ſufficiently evidence the force of theſe. *Vegetius* relates that it vvas uſuall this vvay to ſtrike a man dead, & beat the ſoul out of his body, vvithout ſo much as breaking his armour or fetching blood. *Membris integris læthale tamen vulnus important, & ſine invidia ſanguinis, hoſtis lapidis ictu intereat.*

1 Sam. 17. 49.

Lipſius Polior. l. 4. Dialog. 2.

In the uſe of theſe, many of the Ancients have been of very exquiſite and admirable skill. We read of *ſeven hundred Benjamites left-handed, that could*

Judges 20. 16.

ſling a ſtone at a hairs breadth, and not miſſe. And there is the like ſtoried of a whole Nation amongſt the Indians, vvho from their excellency in this art were ſtyled *Baleares*. They vvere ſo ſtrict in teaching this art unto their young ones; *Vt cibum puer à matre non accipit, niſi quem ipſâ monſtrante percuſſit*, That the mother vvould not give any meat to her child, till (being ſet at ſome diſtance) he could hit it with ſlinging.

ἀπὸ τοῦ βάλλειν. Diodor. Sicul. Biblioth. l. 5. L. Florus Hiſt. l. 3. cap. 8. Io: Boemus Aubanus de moribus gentium l. 3. c. 26.

For the farther illuſtration of this ſubject, concerning the *ſwiftneſſe* of motion, I ſhall briefly ſpecifie ſome particulars concerning the engines of vvar uſed by the Ancients. Amongſt theſe, the moſt famous and admirable vvere thoſe invented by *Archimedes*, by which he did perform ſuch ſtrange exploits, as (vvere they not related by ſo many and ſuch judicious Authours) vvould ſcarce ſeeme credible even to theſe more learned ages. The acts of that famous Engineer, are largely ſet down by [a] *Polybius*, [b] *Tzetzes*, [c] *Proclus*, [d] *Plutarch*, [e] *Livy*,

[a] *Hiſtor. l. 4*
[b] *Hiſtor. Chilias 2. hiſtor. 35.*
[c] *Li. 2. c. 3.*
[d] *Marcellus.*
[e] *Hiſtor. l. 24.*

vy, and divers others. From the first of vvhom alone, vve may have sufficient evidence for the truth of those relations. For besides that he is an Authour noted to be very grave and serious in his discourse; and does solemnly promise in one place that he will relate nothing, but what either he himself was an eye-witnesse of, or else what hee had received from those that were so; I say, besides all this, it is considerable, that he himself was born not above thirty years after the siege of *Syracuse*. And afterwards having occasion to tarry some weeks in that City, when he travelled vvith *Scipio*, he might there perhaps see those engines himself, or at least take his information from such as were eye-vvitnesses of their force: So that there can bee no colourable pretence for any one to distrust the particulars related of them.

Histor. l. 4. juxta initium.

In brief, the sum of their reports is this: When the Romane forces under the conduct of *Marcellus*, had laid siege unto that famous City, (of which

which, both by their former ſucceſſes, and their preſent ſtrength, they could not chuſe but promiſe themſelves a ſpeedy victory;) yet the arts of this one Mathematician, notwithſtanding all their policies and reſolutions, did ſtil beat them back to their great diſadvantage. Whether they were neer the wall or farther from it, they were ſtill expoſed to the force of his engines, καὶ μακρὰν ἀφεστῶτας, καὶ συνέγγυς ὄντας, οὐ μόνον ἀπράκτους παρεσκεύαζε πρὸς τὰς ἰδίας ἐπιβολὰς, ἀλλὰ καὶ διέφθειρε τοὺς πλείστους αὐτῶν. From the multitude of thoſe ſtones and arrows, which he ſhot againſt them, was he ſtyled ἑκατόγχειρ, or *Briareus*. Thoſe defenſive engines that were made by the Romanes in the form of Pent-houſes for to cover the aſſailants from the weapons of the beſieged, theſe would he preſently batter in pieces vvith great ſtones and blocks. Thoſe high towers erected in ſome of the ſhips, out of which the Romanes might more conveniently fight with the defendants on the wall, theſe alſo were ſo

Cæl: Rhod: Ant: lect: l. 2. c. 16.

Pluteus Teſtudo.

ſo broken by his engines, that no Cannon or other inſtrument of Gunpowder, (ſaith a learned man) had they beene then in uſe, could have done greater miſchief. In brief, hee did ſo moleſt them with his frequent and prodigious batteries, that the common ſoldiers were utterly diſcouraged from any hopes of ſucceſſe.

Sir *Walt: Raleigh hiſtor. l.5. c.3. §16.*

What was the particular frame and manner of theſe engines cannot certainly be determined, but to contrive ſuch as may perform the like ſtrange effects, were not very difficult to any one who is thoroughly verſed in the grounds of this art. Though perhaps thoſe of *Archimedes* in reſpect of divers circumſtances, vvere much more exact and proper for the purpoſes to vvhich they vvere intended, then the invention of others could be; He himſelf being ſo extraordinarily ſubtle and ingenious above the common ſort of men.

'Tis probable that the generall kind of theſe engines, were the ſame vvith thoſe that vvere uſed after-

wards

wards amongst the Romanes and other Nations. These were commonly divided into two sorts: styled
{ *Ballistæ.*
{ *Catapultæ.*

Both vvhich names are sometimes used promiscuously; but according to their propriety † *Ballista* does signifie an engine for the shooting of stones, and *Catapulta* for darts or arrows.

Vid. Naudæum de Stud. Militar. l. 2.

† ἀπὸ τοῦ βάλλειν, called also λιθόβολος. πετρόβολος. *Fundibalus. Petraria.*

The former of these was fitted either to carry divers lesser stones, or else one greatest one. Some of these engines made for great stones, have been proportioned to so vast and immense a weight, as may seem almost incredible: which occasioned that in *Lucan,*

Lib. 3.

At saxum quoties ingenti verberis ictu
Excutitur, qualis rupes quã vertice montis
Abscidit impulsu ventorũ adjuta vetustas,
Frangit cuncta ruẽs; nec tantũ corpora pressa
Exanimat, totos cũ sanguine dissipat artus.

With these, they could easily batter down the vvals and Towers of any Fort: So *Ovid.*

Quam

Quam grave balliſtæ mœnia pulſat onus.

And *Statius*--- *Quo turbine bellica quondam*
Librati ſaliunt portarum in clauſtra molares.

The ſtones that were caſt from theſe, were of any form, *Enormes & ſepulchrales*, Milſtones or Tombe-ſtones. Sometimes for the farther annoyance and terror of any beſieged place, they would by theſe throw intoit dead bodies, either of men or horſes, and ſometimes only parts of them as mens heads.

Lipſius Poliorcet. l. 3. Dial. 3.

Athenæus mentions one of theſe *Balliſtæ* that was proportioned unto a ſtone of three talents vveight, each talent being 120 pounds (ſaith *Vitruvius*) ſo that the vvhole vvill amount to 360 pounds. But it is ſtoried of *Archimedes*, that he caſt a ſtone into one of *Marcellus* his ſhips, which was found to weigh ten talents. There is ſome difference amongſt * Authors, concerning what kind of talent this ſhould be underſtood, but it is certain that

Deipnoſoph. l. 5.

Archit. l. 10. c. ult.

λίθον δε-κατάλαν-τον.

Plut. Marcell.

* *Dav. Rivaltus Comen. in Archim. Oper. Ext.*

Naudæus de studio. Milit. l. 2.

that in *Plutarchs* time, (from whō we have this relatiō) one talēt did amount to 120 pounds (saith *Suidas*:) according to vvhich account, the stone it self was of no lesse then twelve hundred pound weight. A weapon (one would think) big enough for those rebell Gyants that fought against the gods. Now the greatest Cannon in use, does not carry above 64 pound vveight, which is far short of the strength in these Mathematicall contrivances. Amongst the Turks indeed, there have been sometimes used such powder instruments, as may equall the force of those invented by *Archimedes*. *Gab. Naudæus* tels us of one bullet shot from them at the siege of *Constantinople*, which was of above 1200 pound vveight; This he affirms from the relation of an Archbishop, who was then present and did see it; the piece could not be drawn by lesse then a hundred and fifty yoak of oxen, vvhich might almost have served to draw away the Town it selfe. But though there hath been perhaps some one

De Stud. Mil. l. 2.

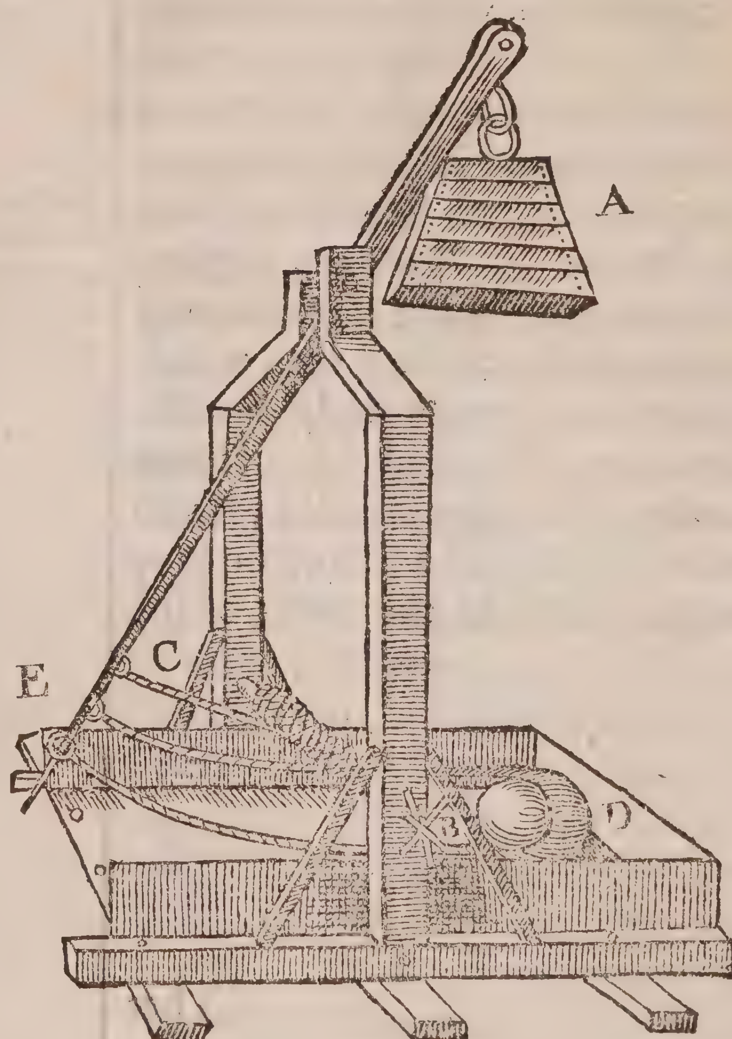
one or two Cannons of ſuch a prodigious magnitude, yet it is certain that the biggeſt in common uſe, does come far ſhort of that ſtrength, which was ordinarily in theſe Mechanical engins.

There are divers figures of theſe *Balliſtæ*, ſet out by *Vegetius*, *Lipſius*, and others; but being without any explication, it is not very facil to diſcover in what their forces did conſiſt.

See *Rob: Valteurius de re Milit.l.*10. *c.*4.

I have here expreſſed one of them moſt eaſie to be apprehended, from the underſtanding of which, you may the better gheſſe at the nature of the reſt.

That



That great box or cavity at *A*, is ſuppoſed to be full of ſome heavy weight, and is forced up by the tur-
ning

ning of the axis and ſpokes *B C.* The ſtone or bullet to be diſcharged being in a kind of ſling at *D*, which when the greater weight *A*, deſcends, will be violently whirled upwards, till that end of the ſling at *E*, coming to the top will flye off, and diſcharge the ſtone as the skilfull Artiſt ſhould direct it.

Cap. XVIII.

Concerning the Catapultæ, or Engines for Arrows.

THe other kind of engine was called *Catapulta,* ἀπὸ τῆς πέλτης, which ſignifies a ſpear or dart, becauſe it was uſed for the ſhooting of ſuch weapons: ſome of theſe were proportioned unto ſpears of twelve cubits long; they did carry with ſo great a force, *ut interdum nimio ardore ſcintillant,* (ſaith *Ammianus*) that the weapons diſcharged from them were ſometimes (if you can beleeve it) ſet on fire by the ſwiftneſſe of their motion.

In Greek καταπέλτης. *Athenæus. Deipnoſ. l.5.*

Lib.23.

Lipſius Poliorcet.l.3. Dial.2.

 The

Diod.Sicul. Biblioth. l.14. Sardus de Invent.Rerum. l.2.

The first invention of these is commonly ascribed to *Dionysius* the yonger, who is said to have made them amongst his other preparations against *Carthage*. But we have good reason to think them of more ancient use, because we read in Scripture that *Vzziah made in Jerusalem engines invented by cunning men to shoot arrows and great stones withall*, though it is likely these inventions vvere much bettered by the experience of after ages.

2 Chron. 26.15.

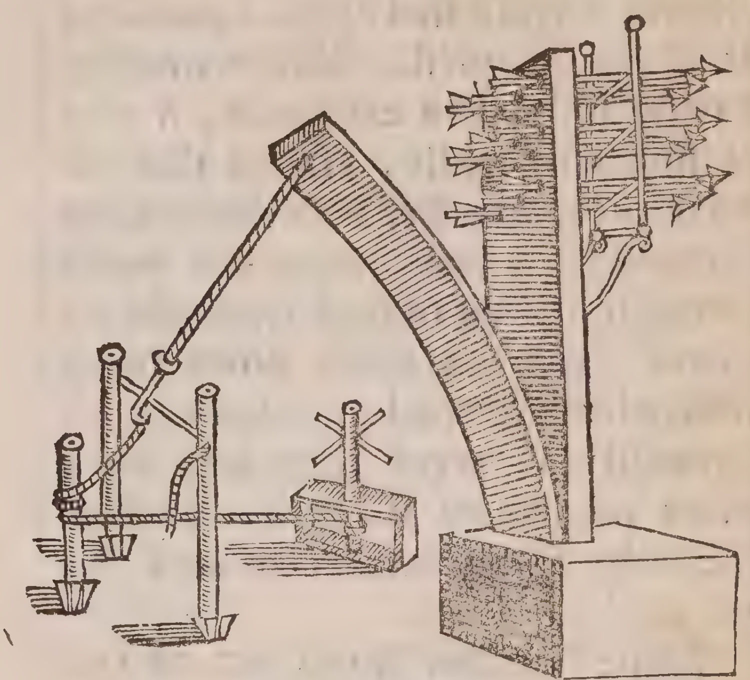
The usuall form of these *Catapultæ*, was much after the manner of great Bows placed on Carriages, and wound up by the strength of severall persons. And from that great force which we find in lesser Bows, we may easily ghesse at the greater power of these other engines. 'Tis related of the Turkish Bow, that it can strike an arrow through a peece of steel or brasse two inches thick, and being headed onely with wood, it pierces Timber of eight inches. Which though it may seem incredible,

Sir Fran: Bacon *Nat. Hist.Exp.* 704.

ble, yet it is attested by the experience of divers unquestionable witnesses: *Barclay* in his *Icon animorum*, a man of sufficient credit, affirms that he was an eye-witnesse, how one of these Bows with a little arrow did pierce through a piece of steel three fingers thick. And yet these Bows being somewhat like the long Bows in use amongst us, were bent only by a mans immediate strength, without the help of any bender or rack that are used to others.

Some Turkish Bows are of that strength, as to pierce a plank of sixe inches in thicknesse, (I speak what I have seen) saith *M. Jo: Greaves* in his *Pyramodographia.* How much greater force then may we conceive to be impressed by the *Catapultæ*?

These were sometimes framed for the discharging of two or three arrows together, so that each of them might bee directed unto a severall aim. But it were as easie to contrive thẽ after the like manner for the carriage of twenty arrows, or more, as in this figure.



Both these kinds of engines when they were used at the siege of any City, were commonly carried in a great wooden Turret (first invented by * *Demetrius*.) It was driven upon four wheels at the bottome, each of its sides being forty five cubits, its height ninety. The whole was divided in nine severall partitions, every one of which did contain divers engines for battery: from its use in the battering and taking of Cities it is styled

* Who was therefore styled *Poliorcetes*. This kind of Turret was first used at the siege of *Cyprus*, & is thus described by *Diodorus Sicul.Biblioth.l.20.*

ſtyled by the name of *Helepolis.*

He that would be informed in the nature of Bows, let him conſult *Merſennus De Balliſtica & Acontiſmologia*, where there are divers ſubtle inquiries and demonſtrations, concerning the ſtrength required to the bending of them to any diſtance. The force they have in the diſcharge according to ſeverall bents, the ſtrength required to be in the ſtring of them, the ſeverall proportions of ſwiftneſſe and diſtance in an arrow ſhot vertically, or horizontally, or tranſverſally.

Thoſe ſtrange effects of the Turkiſh Bow (mentioned before) ſo much exceeding the force of others, which yet require far greater ſtrength for the bending of them, may probably be aſcribed either to the naturall cauſe of *attraction by ſimilitude of ſubſtance* (as the Lord *Bacon* conjectures.) For in theſe experiments the head of the arrow ſhould be of the ſame ſubſtance (whether ſteel or wood) with that which it pierces: Or elſe to that *juſt proportion* betwixt the weight of the arrow, and the ſtrength of the bow, which muſt needs much conduce to the force of it, and may perhaps be more exactly diſcovered in theſe, then it is commonly in others.

Cap. XIX.

A compariſon betwixt theſe ancient engines, and the Gun-powder inſtruments now in uſe.

IT ſhal not be altogether impertinent to inquire ſomewhat concerning the advantages and diſadvantages betwixt thoſe Military offenſive engines, uſed amongſt the Ancients, and thoſe of theſe later ages.

In which inquiry there are two particulars to be chiefly examined:

1. The force of theſe ſeverall contrivances, or the utmoſt that may be done by them.

2. Their price, or the greatneſſe of the charges required unto them.

1. As for the force of theſe ancient

ent inventions, it may ſufficiently appear from thoſe many credible relations mentioned before ; to which may be added that in *Joſephus*, which he ſets down from his own eye-ſight, being himſelf a chief Captain at the ſiege of *Jotapata*, where theſe events happened. He tels us that beſides the multitude of perſons, who were ſlain by theſe Romane Engines, being not able to avoid their force, by reaſon they were placed ſo far off, and out of ſight; Beſides this, they did alſo carry ſuch great ſtones, with ſo great a violence, that they did therewith batter down their wals and Towers. A great bellied woman walking about the City in the day time, had her child ſtruck out of her wombe, and carried half a furlong from her. A ſoldier ſtanding by his Captain *Joſephus*, on the wall, had his head ſtruck off by another ſtone ſent from theſe Romane Engines, and his brains carried three furlongs off.

De bello Iudaico. l. 3. c. 9.

To this purpoſe *Cardan* relates out of *Ammianus Marcellinus. Tanto*

De variet. l. 12. c. 58.

impetu fertur lapis ut uno viso lapide quamvis intacti barbari fuerint ab eo, destiterunt à pugnâ & abierunt. Many forain people being so amazed at the strange force of these Engines, that they durst not contest with those who were masters of such inventions. 'Tis frequently asserted, that bullets have been melted in the air, by that extremity of violent motion imprest from these slings.

Fundáque contorto transverberat aëra plumbo,
Et mediis liquidæ glandes in nubibus errant.

So *Lucan*, speaking of the same Engines.

Inde faces & saxa volant, spatioque solutæ
Aëris & calidæ liquefactæ pondere glandes.

Which relations, though they may seem somewhat poeticall and improbable, yet *Aristotle* himself (*De cœlo lib.* 2. *c.* 7.) doth suppose them as unquestionable. From whence it may be inferred, that the force of these Engines

gines does rather exceed then come ſhort of our Gun-powder inventions.

Add to this that opinion of a learned man (which I cited before) that *Archimedes* in the ſiege of *Syracuſe*, did more miſchief with his Engines, then could have been wrought by any Cannons, had they been then in uſe.

Sir Walt. Raleigh. *Hiſt.l.5. c.3.§ 16.* See *Lipſius de militiâ Romanâ. l.5.*

In this perhaps there may be ſome diſadvantage, becauſe theſe Mathematicall Engines cannot be ſo eaſily and ſpeedily wound up, and ſo certainly levelled as the other may.

2. As for the price or charges of both theſe, it may be conſidered under three particulars:

1. Their making.
2. Their carriage or conveyance.
3. Their charge and diſcharging.

In all which reſpects, the Cannons now in uſe, are of much greater coſt then theſe other inventions.

1. The making or price of theſe Gun-powder inſtruments is extreamly expenſive, as may be eaſily judged by the weight of their materials. A whole

Cannon

Cannõ weighing commonly 8000 l. a half Cannon 5000, a Culverin 4500, a Demiculverin 3000; which whether it be in iron or braſſe, muſt needs be very coſtly, only for the matter of them; beſides the farther charges required for the form and making of them, which in the whole muſt needs amount to ſeverall hundred pounds. Whereas theſe Mathematicall inventions conſiſting chiefly of Timber, and cords, may be much more cheaply made; The ſeverall degrees of them which ſhall anſwer in proportion to the ſtrength of thoſe other, being at the leaſt ten times cheaper; that is, ten Engines that ſhall be of equal force either to a Cannon or Demicannon, Culverin or Demiculverin, may be framed at the ſame price that one of theſe will amount to: So that in this reſpect there is a great inequality.

2. As for their carriage or conveyance; a whole Cannon does require at the leaſt 90 men, or 16 horſes, for the draught of it; a half Cannon 56 men,

men, or 9 horſes; a Culverin 50 men, or 8 horſes; a Demiculverin 36 men, or 7 horſes; Suppoſing the way to be hard and plain, in which notwithſtanding the motion wil be very ſlow. But if the paſſage prove riſing and ſteep, or rotten and dirty, then they will require a much greater ſtrength and charge for the conveyance of them. Whereas theſe other inventions are in themſelves more light (if there be occaſion for the draught of them) being eaſily taken aſunder into ſeverall parts. And beſides, their materials are to be found every where, ſo that they need not be carried up and down at all, but may be eaſily made in the place where they are to be uſed.

3. The materials required to the charging of theſe Gun-powder inſtruments, are very coſtly. A whole Cannon requiring for every charge 40 pound of powder, and a bullet of 64 pounds; a half Cannon 18 pound of powder, and a bullet of 24 pounds; a Culverin 16 pounds of powder, and

a bullet of 19 pounds; a Demi-culverin 9 pounds of powder, and a bullet of 12 pounds: whereas those other Engines may be charged only with stones, or (which may serve for terrour) with dead bodies, or any such materials as every place will afford without any cost.

So then, put all these together: If it be so that those ancient inventions did not come short of these other in regard of force, and if they doe so much excell them in divers other respects; It should seem then, that they are much more commodious then these later inventions, and should be preferred before them. But this inquiry cannot be fully determined without particular experience of both.

CAP. XX.

That it is poßible to contrive ſuch an artificiall motion, as may be equally ſwift with the ſuppoſed motion of the heavens.

FOr the concluſion of this Diſcourſe, I ſhall briefly examine (as before concerning ſlowneſſe) whether it be poſſible to contrive ſuch an artificiall motion, as may be equall unto the ſuppoſed ſwiftneſſe of the heavens. This queſtion hath been formerly propoſed and anſwered by *Cardan*, where he applies it unto the ſwiftneſſe of the moons orb; but that orb being the loweſt of all, and conſequently of a dull and ſluggiſh motion, in compariſon to the reſt; therefore it will perhaps be more convenient to underſtand the queſtion concerning the eight ſphere or ſtarry heaven.

De Variet. Rerum l.9. c.47.

For the true reſolution of this, it ſhould be firſt obſerved, that a materiall ſubſtance is altogether incapable

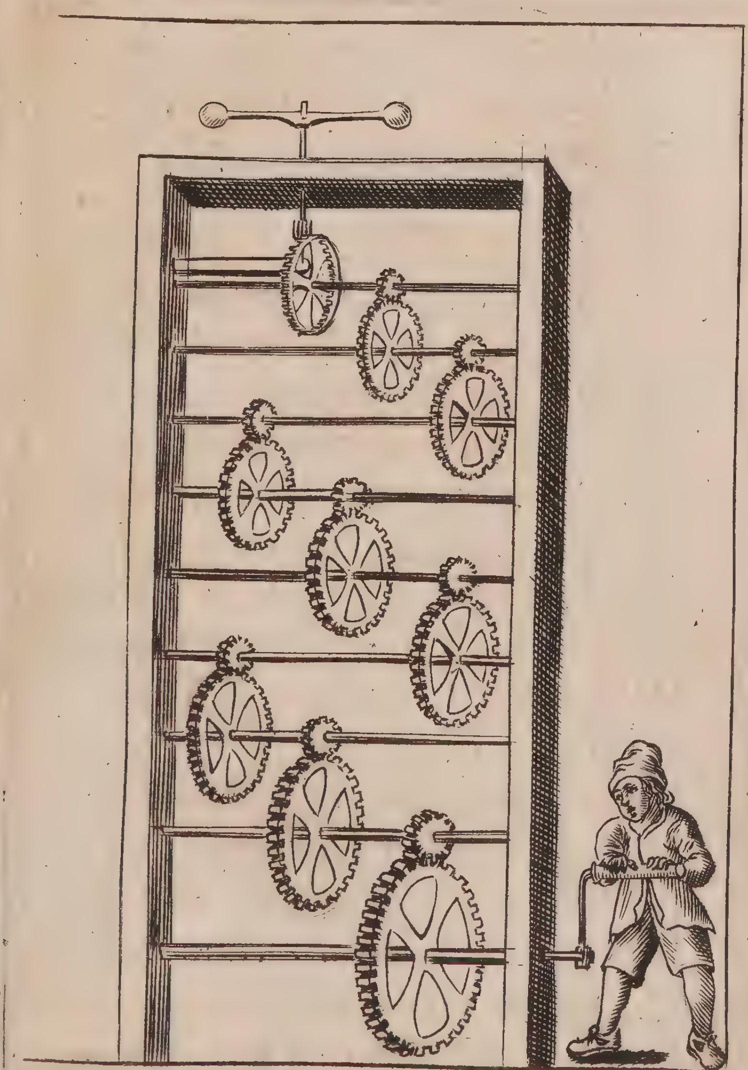
ble of so great a celerity, as is usually ascribed to the celestiall orbs. (as I have proved elsewhere) And therefore the quære is not to be understood of any reall and experimentall, but only notionall, and Geometrical contrivance.

The earth a planet, *prop.9.*

Now that the swiftnesse of motion may be thus increased, according to any conceivable proportion, will be manifest from what hath been formerly delivered, concerning the grounds and nature of slownesse and swiftnesse. For according as we shall suppose the power to exceed the weight: so may the motion of the weight be swifter then that of the power.

But to answer more particularly: Let us imagine every wheel in this following figure to have a hundred teeth in it, and every nut ten:

It



It may then bee evident, that one revolution of the firſt wheel, will turn the nut, and conſequently the ſecond wheel on the ſame axis ten times, the

third

third wheel a hundred times, the fourth 1000 times, the fifth 10000 the ſixth a hundred thouſand times, the ſeventh 1000000 times, the eight 10000000times the ninth 100000000 times, the ſailes 1000000000 times: So that if we ſuppoſe the compaſſe of theſe ſails to be 5 foot, or one pace: and that the firſt wheel is turned about after the rate of one thouſand times in an hower: It wil thē be evident, that the ſails ſhall be turned 1000000000000. times, and conſequently ſhall paſſe 100000000 miles in the ſame ſpace. Whereas a ſtar in the Æquator (according to common *Hypotheſis*) does move but 42398437 miles in an hower, and therefore it is evident that 'tis poſſible Geometrically to contrive ſuch an artificiall motion, as ſhall be of greater ſwiftneſſe, then the ſuppoſed revolutions of the heavens.

DÆDALVS,
OR,
MECHANICALL Motions.

CHAP. I.

The divers kinds of Automata, *or Self-movers. Of Mils, and the contrivance of ſeverall motions by rarefied air. A brief digreſſiō concerning wind-guns.*

AMongſt the variety of artificiall motions, thoſe are of moſt uſe and pleaſure, in which, by the application of ſome continued ſtrength, there is beſtowed a regular and laſting motion.

Theſe we call the αὐτόματα, or *ſelf-movers*: which name in its utmoſt latitude, is ſometimes aſcribed unto thoſe motions, that are contrived from the ſtrength of living creatures, as Chariots, Carts, &c. But in its ſtrictneſſe & propriety, it is onely appliable unto ſuch inventions, wherein the motiō is cauſed either by ſomthing that belongs unto its own frame, or else by some external inanimate agent.

Whence these αὐτόματα are easily distinguishable into two sorts:

1. Those that are moved by something which is extrinsecall unto their own frame, as Mils by water or wind.

2. Those that receive their motion from something that does belong to the frame it self, as clocks, watches, by weights, springs, or the like.

Of both which sorts, there have been many excellent inventions: In the recitall of them, I shall insist chiefly on such as are most eminent for their rarity and subtilty.

Amongst the αὐτόματα that receive their motion frō some externall agent, those of more common use are Mils.

And first, the Water-mils, which are thought to be before the other, though neither the first Author, nor so much as the time wherein they were invented is fully known. And therefore *Polydor Virgil* refers them amongst other fatherlesse inventions. *Pliny* indeed doth mention them, as being commonly used in his time: and yet others

De invent. Rerum, l. 3. c. 18.

Nat. Hist. l. 18. c. 10.

others affirm, that *Bellisarius* in the reign of *Justinian*, did first invent them; Whence *Pancirollus* concludes that it is likely their use was for some space intermitted, and being afterwards renued again, they were then thought to be first discovered. *De Repert. Tit. 22.*

However 'tis certain, that this invention hath much abridged and advantaged the labours of men, who were before condemned unto this slavery, as now unto the Galleys. *Ad Pistrinum.* And as the force of waters hath been usefull for this, so likewise may it be contrived to divers other purposes. Herein doth the skill of an artificer chiefly consist, in the application of these common motions unto various and beneficiall ends, making them serviceable not only for the grinding of corn, but for the preparing of iron or other oare, the making of paper, the elevating of water or the like.

To this purpose also are the Mils that are driven by wind, which are so much more convenient then the other, by how much their situations may be more eaſie and common. The motions of theſe may likewiſe be accommodated to as various uſes as the other, there being ſcarce any labour, to the performance of which, an ingenious artificer cannot apply them. To the ſawing of Timber, the plowing of land, or any other the like ſervice, which cannot be diſpatched the ordinary way, without much toil and tediouſneſſe. And it is a wonderfull thing to conſider, how much mens labours might be eaſed and contracted in ſundry particulars, if ſuch as were well skilled in the prinples and practiſes of theſe Mechanicall experiments, would but thoroughly apply their ſtudies unto the inlargement of ſuch inventions.

There are ſome other motions by wind or air, which (though they are not ſo common as the other, yet) may prove of excellent curioſity, and ſingular uſe. Such was that muſicall inſtrument invented by *Cornelius Dreble*, which being ſet in the ſun-ſhine, would of it ſelf render a ſoft and pleaſant

Marcell. Vrankhein. Epiſt. ad Ioh. Erneſtum.

pleaſant harmony, but being removed into the ſhade, would preſently become ſilent. The reaſon of it was this: the warmth of the ſun, working upon ſome moiſture within it, and rarifying the inward air unto ſo great an extenſion, that it muſt needs ſeek for vent or iſſue, did therby give ſeverall motions unto the inſtrument.

Like that ſtatue of *Memnon* in Ægypt, which makes a ſtrange noiſe when ever the ſun begins to ſhine upon it. *Tacit. Anal.* 2. *Strabo* affirms that he had both ſeen and heard it.

Somewhat of this nature are the *Æolipiles*, which are concave veſſels, conſiſting of ſome ſuch materiall as may indure the fire, having a ſmall hole, at which they are filled with water, and out of which (when the Veſſels are heated) the air doth iſſue forth with a ſtrong and laſting violence. Theſe are frequently uſed for the exciting and contracting of heat in the melting of glaſſes or metals. They may alſo be contrived to be ſerviceable for ſundry other pleaſant uſes, as for the moving of ſails in a chimney corner, the motion of which ſails may be applied to the turning of a ſpit, or the like.

But there is a better invention to

De Varietâ Rerũ l. 12. c. 58.

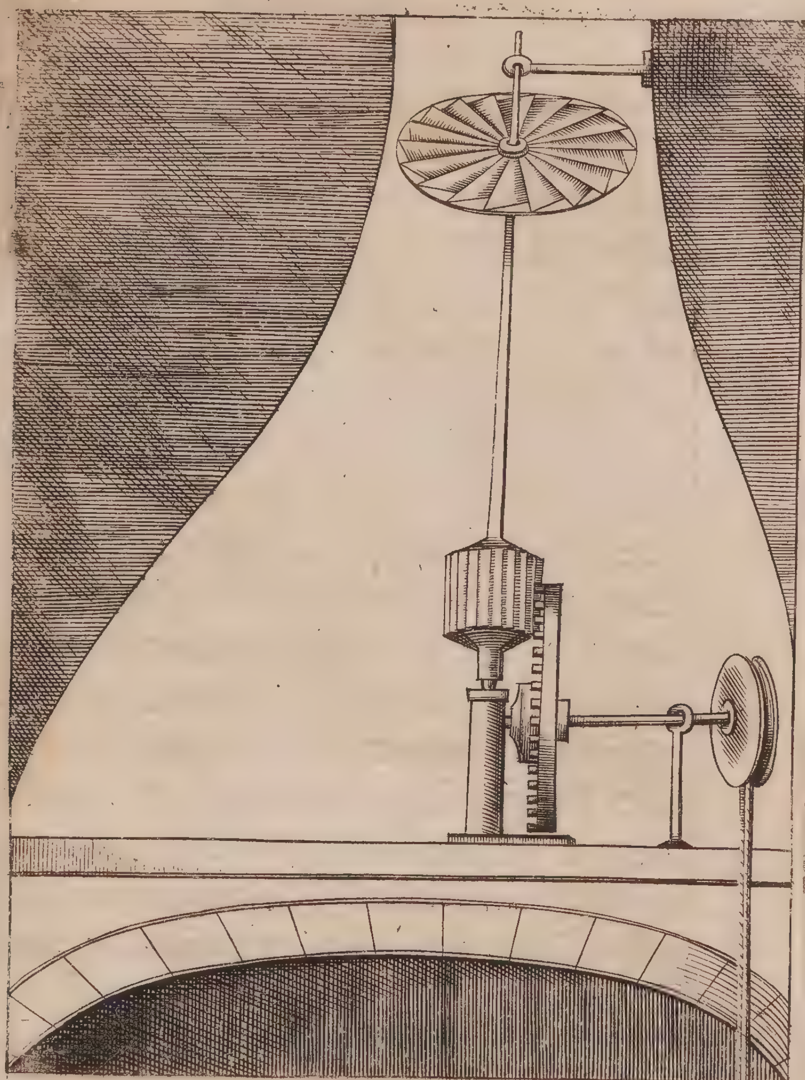
this purpose mentioned in *Cardan*, whereby a spit may be turned (without the help of weights) by the motion of the air that ascends the Chimney; and it may be usefull for the roasting of many or great joints: for as the fire must be increased according to the quantity of meat, so the force of the instrument will be augmented proportionably to the fire. In which contrivance there are these conveniences above the Jacks of ordinary use.

1. It makes little or no noise in the motion.

2. It needs no winding up, but will constantly move of it self, while there is any fire to rarifie the air.

3. It is much cheaper then the other instruments that are commonly used to this purpose. There being required unto it onely a paire of sails, which must bee placed in that part of the chimnie where it begins to be straightned, and one wheel to the axis of which the spit line must be fastned, according to this following Diagram.

The



The motion of theſe ſails may likewiſe be ſerviceable for ſundry other purpoſes, beſides the turning of a ſpit; for the chiming of bels or other muſicall devices; and there cannot be any more pleaſant contrivance for continuall & cheap muſick. It may be uſefull alſo for the reeling of yarn, the rocking of a cradle, with divers the like domeſtick occaſions. For (as was ſaid before) any conſtant motion being given, it is eaſie for an ingenious artificer to apply it unto various ſervices.

Theſe ſails will always move both day and night, if there is but any fire under them, and ſometimes though there bee none. For if the air without be much colder then that within the room, then muſt this which is more warm and rarified, naturally aſcend through the chimney, to give place unto the more condenſed and heavy, which does uſually blow in at every chink or cranny, as experience ſhews.

Unto this kind of motion may be reduced all thoſe repreſentations of living creatures, whether birds, or beaſts, invented by *Cteſibius*, which were for the moſt part performed by the motion of air, being forced up either by *rarefaction*, with fire, or elſe by *compreſſion*, through the fall

of

of ſome heavier body, as water, which by poſſeſſing the place of the aire, did thereby drive it to ſeek for ſome other vent.

I cannot here omit (though it bee not altogether ſo pertinent) to mention that late ingenious invention of the winde-gun, which is charged by the forcible compreſſion of air, being injected through a Syringe; the ſtrife and diſtention of the impriſoned air ſerving by the help of little fals or ſhuts within, to ſtop and keep cloſe the vents by which it was admitted. The force of it in the diſcharge is almoſt equall to our powder-guns. I have found upon frequent trials (ſaith *Merſennus*) that a leaden bullet ſhot from one of theſe gunnes againſt a ſtone wall, the ſpace of 24 paces from it, will be beaten into a thinne plate. It would be a conſiderable addition to this experiment which the ſame Authour mentions a little after, wherby he will make the ſame charge of air to ſerve for the diſcharge of ſeverall arrows or bullets after one another,

Phænomena pneumatica, prop. 32.

nother, by giving the air onely ſo much roome, as may immediately ſerve to impreſſe a violence in ſending away the arrow or bullet, and then ſcrewing it downe again to its former confinement, to fit it for another ſhooting. But againſt this there may be many conſiderable doubts, which I cannot ſtand to diſcuſſe.

CAP. II.

Of a ſailing Chariot, that may without horſes be driven on the land by the wind as ſhips are on the ſea.

THe force of wind in the motion of ſails may be applied alſo to the driving of a Chariot, by which a man may ſail on the land as well as by a ſhip on the water. The labour of horſes or other beaſts, which are uſually applied to this purpoſe, being artificially ſupplied by the ſtrength of winds.

That ſuch Chariots are commonly uſed in the Champion plains of *China*, is frequently affirmed by divers credible Authours. *Boterus* mentions that they have beene tried alſo in *Spaine*, though

De incremento Vrbium l.1. c.10.

though with what ſucceſs he doth not ſpecifie. But above al other experimẽts to this purpoſe, that ſailing Chariot at *Sceveling* in *Holland*, is more eminently remarkable. It was made by the direction of *Stephinus*, & is celebrated by many Authors. * *Walchius* affirms it to be of ſo great a ſwiftneſſe for its motion, and yet of ſo great a capacity for its burden, *Vt in medio freto ſecundis ventis commiſſas naves, velocitate multis paraſangis poſt ſe relinquat, & paucarũ horarum ſpatio, viginti aut triginta milliaria Germanica continuo curſu emetiatur, concreditoſq; ſibi plus minus vectores ſex aut decẽ, in petitũ locũ trãsferat, facillimo illius ad clavũ qui ſedet nutu, quaqua verſum minimo labore velis commiſſum, mirabile hoc continenti currus navigiũ dirigentis.* That it did far exceed the ſpeed of any ſhip, though we ſhould ſuppoſe it to be carried in the open ſea with never ſo proſperous wind: and that in ſome few howers ſpace it would convey 6 or 10 perſons, 20 or 30 German miles, and all this with very little labour of him that ſitteth at the Stearn, who

* *Fabularum decas, Fab. 9.*

who may eaſily guide the courſe of it as he pleaſeth.

That eminent inquiſitive man *Peireskius*, having travelled to *Sceveling* for the ſight & experience of this chariot, would frequently after with much wonder mention the extream ſwiftnes of its motion. *Commemorare ſolebat ſtupore quo correptus fuerat cum vento tranſlatus citatiſſimo non perſentiſcere tamen, nempe tã citus erat quã ventus.* Though the wind were in it ſelf very ſwift and ſtrong, yet to paſſengers in this Chariot, it would not be at all diſcernable, becauſe they did goe with an equall ſwiftneſſe to the wind it ſelfe. Men that ran before it ſeeming to goe backwards, things which ſeeme at a great diſtance being preſently overtaken and left behind. In two howers ſpace it would paſſe from *Sceveling* to *Putten*, which are diſtant from one another above 14 *Horaria milliaria*, (ſaith the ſame Authour) that is more then two and forty miles.

Pet. Gaſſendus. Vita Peireskii, l. 2.

Grotius is very copious and elegant in the celebrating of this invention, and the

the Authour of it in divers Epigrams.

Ventivolam Tiphys deduxit in æquora navim,
Iupiter in ſtellas, æthereamque domum.
In terreſtre ſolum virtus Stevinia, nam nec
Tiphy tuum fuerat, nec Iovis iſtud opus.

Grotii Poemata, Ep.19.

And in another place,

Impoſuit plauſtro vectantem carbaſa, malum
An potius navi, ſubdidit ille rotas?
--Scandit aquas navis currus ruit aere prono,
Et merito dicas hic volat, illa natat.

Ep.5.

Theſe relations did at the firſt ſeem unto me, (and perhaps they will ſo to others) ſomewhat ſtrange & incredible. But upon farther enquiry I have heard them frequently atteſted from the particular eye-ſight & experience of ſuch eminent perſons, whoſe names I dare not cite in a buſineſſe of this nature, which in thoſe parts is ſo very common, and little obſerved.

I have not met with any Authour who doth treat particularly concerning the manner of framing this Chariot, though *Grotius* mentions an elegant deſcription of it in copper by one *Geynius*: and *Hondius* in one of his large maps of *Aſia*, does give another conjecturall deſcription of the like Chariots uſed in *China*.

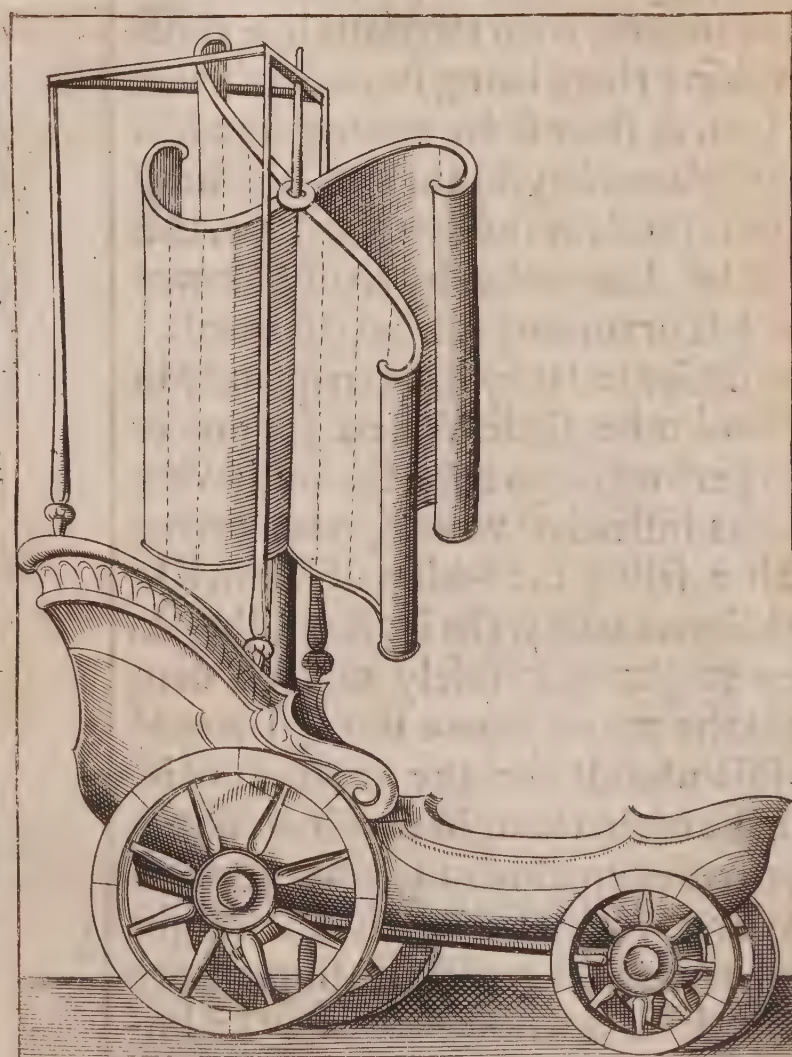
Epig.20, & 21.

The form of it is related to be very ſimple & plain, after this manner.

The body of it being ſomewhat like a boat, moving upon 4 wheels of an equall bignes, with two ſails like thoſe in a ſhip; there being ſome cõtrivance to turn & ſteer it by moving a rudder wch is placed beyõd the two hindmoſt wheels: and for the ſtopping of it, this muſt be done either by letting downe the ſail or turning it from the wind.

Of this kind they have frequently in *Holland* other little Veſſels for one or two perſons to go upon the ice, having ſledges inſtead of wheels, being driven with a ſaile; the bodies of them like little boats, that if the ice ſhould break, they might yet ſafely carry a man upon the water, where the ſail would be ſtill uſefull for the motion of it.

I have often thought that it would be worth the experiment to enquire, whether or no ſuch a ſailing chariot might not be more conveniently framed wth movable ſails, whoſe force may be impreſt from their motion, equivalent to thoſe in a wind-mill. Their formoſt wheels (as in other Chariots) for the greater facility, being ſomewhat lower then the other, anſwerable to this figure.



In which the ſails are ſo contrived, that the wind from any Coaſt will have a force upon them to turn them about, and the motion of theſe ſails muſt needs turn the wheels, and conſequently carry on the Chariot it ſelf to any place (though fully againſt the wind) whither it ſhall be directed.

The chief doubt will be, whether in ſuch a contrivance every little ruggedneſſe or unevennes of the ground, will not cauſe ſuch a jolting of the Chariot as to hinder the motion of its ſails. But this perhaps (if it ſhould prove ſo) is capable of ſeverall remedies.

I have often wondred, why none of our Gentry who live near great Plaines, and ſmooth Champions, have attempted any thing to this purpoſe. The experiments of this kind being very pleaſant, and not coſtly: what could be more delightfull or better husbandry, then to make uſe of the *wind* (which coſts nothing, and eats nothing) in ſtead of *horſes*? This being very eaſie to be effected by thoſe, the convenience of whoſe habitations doth accommodate them for ſuch experiments.

Cap. III.

Concerning the fixed Automata, *Clocks, Spheres, repreſenting the heavenly motions: The ſeverall excellencies that are moſt commendable in ſuch kind of contrivances.*

THe ſecond kind of αὐτόματα were deſcribed to be ſuch Engines, as did receive a regular and laſting motion from ſomething belonging to their own frame, whether weights, or ſprings, &c.

They are uſually diſtinguiſhed into αὐτόματα
{ ϛάτα, fixed and ſtationary.
{ ὑπάγοντα, moveable and tranſient.

1. The fixed are ſuch as move only according to their ſeverall parts, and not according to their whole frame; In which, though each wheel hath a diſtinct rotation, yet the whole doth ſtill remain unmoved. The chiefeſt kind

kind of theſe are the clocks & watches in ordinary uſe, the framing of which is ſo commonly known by every Mechanick, that I ſhall not trouble the Reader with any explication of it. He that deſires fuller ſatisfaction, may ſee them particularly deſcribed by * *Cardan*, † D. *Flood*, and others.

* *De Variet. Rer. l.* 9. *c.* 47.
† *Tract.* 2. *part.* 7 *l.* 1. *cap.* 4.

The firſt invention of theſe (ſaith *Pancirollus*) was taken from that experiment in the multiplication of wheels mentioned in *Vitruvius*, where he ſpeaks of an inſtrument whereby a man may know how many miles or paces he doth goe in any ſpace of time, whether or no he doe paſſe by water in a boat or ſhip, or by land in a chariot or coach: they have been contrived alſo into little pocket inſtruments, by which after a man hath walked a whole day together, he may eaſily know how many ſteps he hath taken. I forbear to enter upon a larger explication of theſe kind of Engines, becauſe they are impertinent unto the chief buſineſſe that

Repert. Tit. 10.
Architect. l. 10. *c.* 14.

I have propoſed for this diſcourſe. The Reader may ſee them more particularly deſcribed in the above cited place of *Vitruvius*, in * *Cardan*, † *Beſſonius*, and others; I have here only mentioned them, as being the firſt occaſion of the chiefeſt αὐτόματα that are now in uſe.

* *Subtil. l.* 18.
† *Theatrum inſtrumentorum. Wecker de ſecretis. l.* 15. *c.* 32.

Of the ſame kind with our clocks and watches (though perhaps more elaborate and ſubtle) was that ſphere invented by *Archimedes*, which did repreſent the heavenly motions: the diurnall and annuall courſes of the ſun, the changes and aſpects of the Moon, &c. This is frequently celebrated in the writings of the Ancients, particularly in that known *Epigram* of *Claudian*:

Mentioned by *Cicero. Tuſcul. Quæſt. l.* 1. *item De Nat. Deorũ l.* 2.

Jupiter in parvo cum cerneret æthera vitro,
Riſit, & ad ſuperos talia dicta dedit;
Huccine mortalis progreſſa potentia curæ?
Jam meus in fragili luditur orbe labor.
Jura poli, rerumque fidem, legeſque Deorum,
Ecce Syracuſius tranſtulit arte ſenex.
*Incluſus variis famulatur * ſpiritus aſtris,*
Et vivum certis motibus urget opus.

* The ſecret force frõ which the motion was impreſſed.

Per-

Percurrit proprium mentitus Signifer annum;
Et simulata novo Cynthia mense redit.
Jamq; suum volvens audax industria mundũ
Gaudet, & humanâ sidera mente regit.
Quid falso insontem tonitru Salmonea miror?
Æmula naturæ parva reperta manus.

Excellently Translated by *T. Randolph.*

Iove saw the heavens fram'd in a little *glasse,*
And laughing, to the gods these words did passe;
Comes then the power of mortall cares so far?
In brittle orbs my labours acted are.
The statutes of the Poles, the faith of things,
The laws of Gods, this *Syracusian* brings
Hither by art: Spirits inclos'd attend
Their severall spheres, and with set motions bend
The living work: each year the feigned Sun,
Each month returns the counterfeited Moon.
And viewing now her world, bold industry
Grows proud,to know the heavens his subjects be.
Beleeve,*Salmoneus* hath false thunders thrown,
For a poor hand is natures rivall grown.

But that this Engine should be made of glasse, is scarce credible, *Lactantius* mentioning the relation of it, affirms it to consist of brasse, which is more likely. It may be the outside or case was glasse, and the frame it self of brasse. *Cœlius Rhodoginus*, speaking of the wondrous art in the contrivance of

Instit.l.2. c.5.

Antiq.lect. l 2.c.16.

of this ſphere, breaks out into this quære. *Nonne igitur miraculorum omnium, maximum miraculum eſt homo?* He might have ſaid *Mathematicus*: and another to this purpoſe, *Sic manus ejus naturam, ut natura ipſa manum imitata putetur*. *Pappus* tels us, that *Archimedes* writ a Book *de Sphæropœia*, cõcerning the manner of framing ſuch Engines, and after him *Poſidonius* compoſed another diſcourſe on the ſame ſubject, though now either the ignorance or the envy of time hath deprived us of both thoſe works And yet the art it ſelf is not quite periſhed, for we read of divers the like contrivãces in theſe latter times. *Agrippa* affirms that he himſelf had ſeen ſuch a ſphere, & *Ramus* tels us how he beheld two of them in *Paris*, the one brought thither amongſt other ſpoiles from *Sicily*, and the other out of *Germany*. And it is commonly reported, that there is yet ſuch a ſphere at *Strasburg* in *Germany*. * *Rivaltus* relates how *Marinus Burgeſius* a *Norman* made two of them in *France* for the King.

Guid. Vbaldus præf. ad Mechan.

Collect. Mathem. Prœm. ad l. 8.

De vanit. Sciẽt. c. 22. *Schol. Mathem. l. 1.* So *Cardan* too, *l. 17.* *Monanth. in Mecha. Ariſt. Com. c. 1.* *Dr* Hackwell, *Apol. l. 2. c. 10. ſect. 1.* * *De vitâ Archimedis.*

And perhaps these latter (saith he) were more exact then the former, because the heavenly revolutions are now much better understood then before. And besides it is questionable, whether the use of steel springs was known in those ancient times; the application of which unto these kind of spheres, must needs be much more convenient then weights.

'Tis related also of the Consull *Boethius*, that amongst other Mathematicall contrivances, (for which he was famous) he made a sphere to represent the Suns motion, which was so much admired, and talked of in those times, that *Gundibaldus* King of *Burgundy*, did purposely send over Embassadors to *Theodoricus* the Emperour, with intreaties that he would be a means to procure one of these spheres from *Boethius*; the Emperor thinking hereby to make his kingdom more famous and terrible unto forain Nations, doth write an Epistle to *Boethius*, perswading him to send this instrument. *Quoties non sunt credituri*

Cassiodor. Chron. Pet. Bertius præf. ad Consolat. Philos.

quod viderint? Quoties hanc veritatem luſoria ſomnia putabunt? Et quando fuerint à ſtupore converſi, non audedebunt ſe æquales nobis dicere, apud quos ſciunt ſapientes talia cogitaſſe. So much were all theſe kind of inventions admired in thoſe ruder & darker times: whereas the inſtruments that are now in uſe amongſt us (though not ſo much extolled) yet doe altogether equall (if not exceed) the other, both in uſefulneſſe and ſubtilty. The chiefeſt of theſe former Engines receiving their motion from weights, and not from ſprings, (which as I ſaid before) are of later and more excellent invention.

Polyd. Virgil. de Invent. rerum l 2 c. 5. Cardan Subtil. l. 17.

The particular circumſtances for which the *Automata* of this kind, are moſt eminent, may be reduced to theſe four.

1. The laſtingneſſe of their motion, without needing of any new ſupply; for which purpoſe there have been ſome watches contrived to continue without winding up for a week together, or longer.

2. The

2. The easinesse and simplicity of their composition; Art it self being but the facilitating and contracting of ordinary operations, therefore the more easie and compendious such inventions are, the more artificial should they be esteemed. And the addition of any such unnecessary parts, as may be supplied some other way, is a sure sign of unskilfulnesse and ignorance. Those antiquated engines that did consist of such a needlesse multitude of wheels, and springs, and screws, (like the old *hypothesis* of the heavens) may be compared to the notions of a confused knowledge, which are always full of perplexity and complications, and seldome in order; whereas the inventions of art are more regular, simple, and perspicuous, like the apprehensions of a distinct and thoroughly informed judgement. In this respect the manner of framing the ordinary *Automata*, hath been much bettered in these later times above the former, and shall hereafter perhaps be yet more advantaged.

These

Theſe kind of experiments (like all other humane arts) receiving additions from every days experiment.

To this purpoſe there is an invention conſiſting only of one hollow orb or wheel, whereby the howers may be as truly diſtinguiſhed, as by any ordinary clock or watch. This wheel ſhould be divided into ſeverall cavities, through each of which ſucceſſively either ſand or water muſt be contrived to paſſe; the heavineſſe of theſe bodies (being always in the aſcending ſide of the wheel) muſt be counterpoiſed by a plummet that may be faſtned about the pulley on the axis: this plummet will leiſurely deſcend, according as the ſand by running out of one cavity into the next, doth make the ſeverall parts of the wheel lighter or heavier, and ſo conſequently there will be produced an equall and laſting motion, which may be eaſily applyed to the diſtinction of howers.

3. The multitude and variety of thoſe ſervices for which they may

be uſefull. Unto this kind may we refer thoſe watches, by which a man may tell not only the hower of the day, but the minute of the hower, the day of the month, the age and aſpects of the Moone, &c. Of this nature likewiſe was that larum mentioned by *Walchius*, which though it were but two or three inches big, yet would both wake a man, and of it ſelf light a candle for him at any ſet hower of the night. And thoſe weights or ſprings which are of ſo great force as to turn a mill, (as ſome have been contrived) may be eaſily applyed to more various and difficult labours.

Fab.9.

Ramel. fig. 130.

4. The littleneſſe of their frame. *Nunquam ars magis quam in minimis nota eſt* (ſaith *Aquinas.*) The ſmalneſſe of the Engine doth much commend the skill of the artificer; to this purpoſe there have been watches contrived in the form and quantity of a Jewell for the ear, where the ſtriking of the minutes may conſtantly whiſper unto us, how our lives doe ſlide away

Jacks no bigger then a Walnut to turn any joint of meat.

De subtil. l.2.item l.17.

away by a swift succession. *Cardan* tels us of a Smith who made a watch in the Jewell of a ring, to be worn on the finger, which did shew the howers, (*non solum sagitta, sed ictu*) not only by the hand, but by the finger too (as I may say) by pricking it every hower.

Cap. IV.

Of the moveable and Gradient Automata, representing the motions of living creatures, various sounds, of birds, or beasts, and some of them articulate.

THus much of those Automata, which were said to be fixed and stationary.

The other kind to be inquired after, are those that are moveable and transient, which are described to be such engines as move not only according to their severall parts, but also according to their whole frames. These are again distinguishable into two sorts:

1. *Gradient.*
2. *Volant.*

1. The *Gradient* or *ambulatory*, are such as require some *basis* or bottome to uphold them in their motions. Such were those strange inventions (commonly attributed to *Dædalus*) of self-moving statues, which (unlesse they were violently detained) would of themselves run away. * *Aristotle* affirms that *Dædalus* did this by putting quick-silver into them. But this would have been too grosse a way for so excellent an artificer, it is more likely that he did it with wheels & weights. Of this kind likewise were *Vulcans Tripodes*, celebrated by *Homer*, that were made to move up and down the house, and fight with one another. He might as well have contrived them into Journey-men statues, each of which with a hammer in his hand should have worked at the forge.

Plato in Menone. Arist. Polit. l. 1. c. 3.

* *De Anima l. 1. c. 3.*

Iliad. 18.

There have been also chariots driven by the force of a spring contrived within them.

But amongst these fighting images, that in *Cardan* may deserve a mention, which holding in its hand a golden apple, beautified with many costly Jewels;

De Variet. rerum l. 12. c. 58.

Jewels; if any man offered to take it, the ſtatue preſently ſhot him to death. The touching of this apple ſerving to diſcharge ſeverall ſhort bows, or other the like inſtruments that were ſecretly couched within the body of the image. By ſuch a treachery was King *Chennetus* murdered (as *Boethius* relates.

It is ſo common an experiment in theſe times to repreſent the perſons and actions of any ſtory by ſuch ſelf-moving images, that I ſhall not need to explain the manner how the wheels and ſprings are contrived within them.

Fab.9. There have been other inventions to move on the water. *Navigium ſponte mobile, ac ſui remigii autorem, faciam nullo negotio,* ſaith *Scaliger, Exerc.*326.

Amongſt theſe gradient *Automata,* that iron ſpider mentioned in *Walchius,* is more eſpecially remarkable, which being but of an ordinary bigneſſe, beſides the outward ſimilitude, (wch was very exact) had the ſame kind of motions with a living ſpider, and did creep up and down as if it had been alive. It muſt needs argue a wonderfull art, and accurateneſſe, to contrive all the inſtruments requiſite for ſuch a motion in so small a frame.

There have been also other motions contrived from Magneticall qualities, which will shew the more wonderful, because there is no apparent reason of their motion, there being not the least contiguity or dependence upon any other body that may occasion it; but it is all one as if they should move up and down in the open air. Get a glasse sphere, fill it with such liquors as may be clear of the same colour, immixable, such as are oyl of tartar, and spirit of wine: In which, it is easie so to poise a little globe or other statue, that it shall swim in the center. Under this glasse sphere, there should be a loadstone concealed, by the motion of which, this statue (having a needle touched within it) will move up and down, and may be contrived to shew the hower or sign. See severall inventions of this kinde in *Kircher de arte Magnetica, l.*2.

There have been some artificiall images, which besides their severall postures in walking up and downe, have

have been made alſo to give ſeverall ſounds, whether of birds, as Larks, Cuckoes, &c. or beaſts, as Hares, Foxes. The voices of which creatures ſhall be rendred as clearly and diſtinctly, by theſe artificiall images, as they are by thoſe naturall living bodies, which they repreſent.

There have been ſome inventions alſo which have been able for the utterance of articulate ſounds, as the ſpeaking of certain words. Such are ſome of the Ægyptian idols related to be. Such was the brazen head made by Friar *Bacon*, and that ſtatue in the framing of which *Albertus Magnus* beſtowed thirty years, broken by *Aquinas*, who came to ſee it, purpoſely that he might boaſt, how in one minute he had ruined the labour of ſo many years.

Cœl.Rhod. lect. Ant. l.2.c.17. Maiolus Colloq.

Now the ground and reaſon how theſe ſounds were contrived, may be worth our inquiry.

Firſt then, for thoſe of birds or beaſts, they were made from ſuch pipes or cals, as may expreſſe the ſeverall

verall tones of thoſe creatures which are repreſented: theſe cals are ſo commonly known and uſed, that they need not any further explication.

But now about articulate ſounds there is much greater difficulty. *Walchius* thinks it poſſible entirely to preſerve the voice, or any words ſpoken, in a hollow trunk, or pipe, and that this pipe being rightly opened, the words will come out of it in the ſame order wherein they were ſpoken. Somewhat like that cold Countrey, where the peoples diſcourſe doth freeze in the air all winter, and may be heard the next Summer, or at a great thaw. But this conjecture will need no refutation. *Fab. 9.*

The more ſubſtantiall way for ſuch a diſcovery, is by marking how nature her ſelf doth imploy the ſeverall inſtruments of ſpeech, the tongue, lips, throat, teeth, &c. To this purpoſe the Hebrews have aſſigned each letter unto its proper inſtrument. And beſides, we ſhould obſerve what inarticulate ſounds doe reſemble any of the particular letters. Thus we may note the trembling of water to be like the letter *L*, the quenching of hot things to the letters *Z*, the ſound of ſtrings, unto the letter *Ng*, the jirking of a ſwitch the letter *Q*, &c. By an exact obſervation of theſe particulars, it is (perhaps) poſſible to make a ſtatue ſpeak ſome words.

Bacon Nat. hiſt. exper. 139, 200.

CAP. V.

Concerning the poſsibility of framing an Ark for ſubmarine Navigations. The difficulties and conveniences of ſuch a contrivance.

IT will not be altogether impertinent unto the diſcourſe of theſe gradient *Automata*, to mention what *Merſennus* doth ſo largely and pleaſantly deſcant upon, concerning the making of a ſhip, wherein men may ſafely ſwim under water.

Tract de Magnetis proprietatibus.

That ſuch a contrivance is feaſible and may be effected, is beyond all queſtion, becauſe it hath been already dy experimented here in *England* by *Cornelius Dreble*, but how to improve it unto publike uſe and advantage, ſo as to be ſerviceable for remote voyages, the carrying of any conſiderable number of men, with proviſions and commodities, would be of ſuch excellent uſe as may deſerve ſome further inquiry.

Concerning which there are two things chiefly conſiderable:

The { many difficulties with their remedies.
great conveniences. }

1. The difficulties are generally reducible to theſe three heads:

1. The letting out, or receiving in any thing, as there ſhall be occaſion without the admiſſion of water. If it have not ſuch a convenience, theſe kind of voyages muſt needs be very dangerous and uncomfortable, both by reaſon of many noiſome offenſive things, which ſhould be thruſt out, and many other needfull things which ſhould be received in. Now herein will conſiſt the difficulty, how to con-

trive the opening of this veſſell ſo, that any thing may be put in or out, and yet the water not ruſh into it with much violence,as it doth uſually in the leak of a ſhip.

In which caſe this may be a proper remedy; let there be certain leather bags made of ſeverall bigneſſes,which for the *matter* of them ſhould be both *tractable* for the uſe and managing of them, and *ſtrong* to keep out the water, for the *figure* of them being long and open at both ends. Anſwerable to theſe, let there be divers windows, or open places in the frame of the ſhip, round the ſides of which one end of theſe bags may be fixed, the other end coming within the ſhip being to open and ſhut as a purſe. Now if we ſuppoſe this bag thus faſtned, to be tyed cloſe about towards the window, then any thing that is to be ſent out, may be ſafely put into that end within the ſhip, which being again cloſe ſhut,and the other end looſened, the thing may be ſafely ſent out without the admiſſion of any water.

So

So again, when any thing is to be taken in, it muſt be firſt received into that part of the bag towards the window, which being (after the thing is within it) cloſe tyed about, the other end may then be ſafely opened. It is eaſie to conceive, how by this means any thing or perſon may be ſent out, or received in, as there ſhall be occaſion, how the water, which will perhaps by degrees leak into ſeveral parts, may be emptyed out again, with divers the like advantages. Though if there ſhould be any leak at the bottome of this Veſſell, yet very little water would get in, becauſe no air could get out.

2. The ſecond difficuly in ſuch an Ark will be the *motion* or *fixing* of it according to occaſion; The *directing* of it to ſeverall places, as the voyage ſhall be deſigned, without which, it would be very uſeleſſe, if it were to remain only in one place, or were to remove only blindfold, without any certain direction; And the contrivance of this may ſeem very diffi-

cult, becauſe theſe ſubmarine Navigators will want the uſuall advantages of winds and tides for motion, and the ſight of the heavens for direction.

But theſe difficulties may be thus remedied; As for the *progreſſive* motion of it, this may be effected by the help of ſeverall Oars, which in the outward ends of them, ſhall be like the fins of a fiſh to contract and dilate. The paſſage where they are admitted into the ſhip being tyed about with ſuch leather bags (as were mentioned before) to keep out the water. It will not be convenient perhaps that the motion in theſe voyages ſhould be very ſwift, becauſe of thoſe obſervations and diſcoveries to be made at the bottome of the ſea, which in a little ſpace may abundantly recompenſe the ſlowneſſe of its progreſſe.

If this Ark be ſo ballaſt as to be of equall weight with the like magnitude of water, it will then be eaſily movable in any part of it.

As for the *aſcent* of it, this may be eaſily contrived, if there be ſome great

weight

weight at the bottome of the ſhip (being part of its ballaſt) which by ſome cord within may be looſened from it; As this weight is let lower, ſo will the ſhip aſcend from it (if need be) to the very ſurface of the water; and again, as it is pulled cloſe to the ſhip, ſo will it *deſcend*.

For *direction* of this Ark, the Mariners needle may be uſefull in reſpect of the *latitude* of places, and the courſe of this ſhip being more regular then others, by reaſon it is not ſubject to Tempeſts or unequall winds, may more certainly guide them in judging of the *longitude* of places.

3. But the greateſt difficulty of all will be this, how the air may bee ſupplyed for reſpiration: How conſtant fires may be kept in it for light and the dreſſing of food, how thoſe viciſſitudes of rarefaction and condenſation may be maintained.

It is obſerved, that a barrell or cap, whoſe cavity will contain eight cubicall feet of air, will not ſerve a Urinator or Diver for reſpiration, above one quarter of an hower; the breath which is often ſucked in and out, being ſo corrupted by the mixture of vapours, that nature rejects it as unſerviceable. Now in an hower a man will need at leaſt 360 reſpirations, betwixt every one of which there ſhall be 10 ſecond minutes, and conſequently a great change and ſupply of air will be neceſſary for many perſons, and any long ſpace.

And ſo likewiſe for the keeping of fire; a cloſe Veſſell containing 10 cubicall feet of air, will not ſuffer a wax candle of an ounce to burn in it above an hower before it be ſuffocated, though this proportion (ſaith *Merſennus*) doth not equally increaſe for ſeverall lights, becauſe four flames of an equall magnitude will be kept alive the ſpace of 16 ſecond minutes, though one of theſe flames alone in the ſame Veſſell will not laſt above 25, or at moſt 30 ſeconds, which may be eaſily tryed in large glaſſe bottles, having wax candles lighted in them, and with their mouths inverted in water.

For

For the reſolution of this difficulty, though I will not ſay that a man may by cuſtome (which in other things doth produce ſuch ſtrange incredible effects) be inabled to live in the open water as the fiſhes doe, the inſpiration and expiration of water ſerving inſtead of air, this being uſuall with many fiſhes that have lungs; yet it is certain that long uſe and cuſtome may ſtrengthen men againſt many ſuch inconveniences of this kind, which to unexperienced perſons may prove very hazzardous: and ſo it will not perhaps be unto theſe ſo neceſſary, to have the air for breathing ſo pure and defecated as is required for others.

But further there are in this caſe theſe three things conſiderable.

1. That the Veſſell it ſelf ſhould be of a large capacity, that as the air in it is corrupted in one part, ſo it may be purified and renued in the other: or if the meer refrigeration of the air would fit it for breathing, this might be ſomewhat helped with bellows,

bellows, which would cool it by motion.

2. It is not altogether improbable, that the lamps or fires in the middle of it, like the reflected beams in the first Region, rarefying the air, and the circumambient coldnesse towards the sides of the Vessell, like the second Region, cooling and condensing of it, would make such a vicissitude and change of air, as might fit it for all its proper uses.

Harmon. l.4. prop.6. Monit.5.

3. Or if neither of these conjectures will help, yet *Mersennus* tels us in another place, that there is in *France* one *Barrieus* a Diver, who hath lately found out another art, whereby a man might easily continue under water for six howers together, and whereas ten cubicall feet of air will not serve another Diver to breath in for half an hower, he by the help of a cavity, not above one or two foot at most, will have breath enough for six howers, and a lanthorn scarce above the usuall size to keep a candle burning as long as a man please, which (if

(if it be true, and were commonly known) might be a ſufficient help againſt this greateſt difficulty.

As for the many advantages and conveniences of ſuch a contrivance, it is not eaſie to recite them.

1. 'Tis *private*; a man may thus goe to any coaſt of the world inviſibly, without being diſcovered or prevented in his journey.

2. 'Tis *ſafe*; from the uncertainty of *Tides*, and the violence of *Tempeſts*, which doe never move the ſea above five or ſix paces deep. From *Pirates* and *Robbers* which do ſo infeſt other voyages; From ice and great froſts, which doe ſo much endanger the paſſages towards the Poles.

3. It may be of very great advantage againſt a Navy of enemies, who by this means may be undermined in the water and blown up.

4. It may be of ſpeciall uſe for the relief of any place that is beſieged by water, to convay unto them inviſible ſupplies: and ſo likewiſe for the ſurpriſall of any place that is acceſſible by water.

5. It may be of unſpeakle benefit for ſubmarine experiments and diſcoveries: as

The ſeverall proportions of ſwiftneſſe betwixt the aſcent of a bladder, cork, or any other light ſubſtance in compariſon to the deſcent of ſtones or lead. The deep caverns and ſubterraneous paſſages where the ſea-water in the courſe of its circulation, doth vent it ſelf into other places, and the like. The nature and kinds of fiſhes, the ſeverall arts of catching them, by alluring them with lights, by placing divers nets about the ſides of this Veſſell, ſhooting the greater ſort of them with guns, which may be put out of the ſhip by the help of ſuch bags as were mentioned before, with divers the like artifices and treacheries, which may be more ſucceſſively practiſed by ſuch who live ſo familiarly together. Theſe fiſh may ſerve not only for food, but for fewell likewiſe, in reſpect of that oyl which may be extracted from them; the way of dreſſing meat by lamps, being

ing in many reſpects the moſt convenient for ſuch a voyage.

The many freſh ſprings that may probably be met with in the bottome of the ſea, will ſerve for the ſupply of drink and other occaſions.

But above all, the diſcovery of ſubmarine treaſures is more eſpecially conſiderable, not only in regard of what hath been drowned by racks, but the ſeverall precious things that grow there, as Pearl, Corall, Mines, with innumerable other things of great value, which may be much more eaſily found out, and fetcht up by the help of this, then by any other uſually way of the Urinators.

To which purpoſe, this great Veſſell may have ſome leſſer cabines tyed about it, at various diſtances, wherein ſeverall perſons as Scouts, may be lodged for the taking of obſervations, according as the Admirall ſhall direct them. Some of them being frequently ſent up to the ſurface of the water, as there ſhall be occaſion.

All kind of arts and manufactures may be exercised in this Vessell. The observations made by it, may bee both written, and (if need were) printed here likewise. Severall Colonies may thus inhabit, having their children born and bred up without the knowledge of land, who could not chuse but be amazed with strange conceits upon the discovery of this upper world.

I am not able to judge what other advantages there may be suggested, or whether experiment would fully answer to these notionall conjectures. But however, because the invention did unto me seem ingenious and new, being not impertinent to the present enquiry, therefore I thought it might be worth the mentioning.

Cap. VI.

Of the volant Automata, Archytas *his Dove, and* Regiomontanus *his Eagle. The poſsibility and great uſefulneſſe of ſuch inventions.*

THe *volant* or flying *Automata* are ſuch Mechanicall contrivances, as have a ſelf-motion, whereby they are carried aloft in the open air, like the flight of Birds. Such was that wooden Dove made by *Archytas*, a Citizen of *Tarentum*, and one of *Plato's* acquaintance. And that wooden Eagle framed by *Regiomontanus* at *Noremberg*, which by way of triumph, did fly out of the City to meet *Charles* the fift. This later Author is alſo reported to have made an iron fly, *Quæ ex artificis manu egreſſa, convivas circumvolitavit, tandemque veluti defeſſa in Domini manus reverſa eſt*, which when he invited any of his friends, would fly to each of them round the table, and at length (as being weary) return unto its Maſter.

Diog. Laer. l. 8.
Pet. Crinitus de honeſt. diſcip. l. 17. c. 12.

Ramus Schol. Mathem. l. 2.

Dubartas 6 days 1 W.
I. Dee Preface to *Euclid.*

Cardan

De Variet. rerum lib. 12.c.58.

Cardan ſeems to doubt the poſſibility of any ſuch contrivance; his reaſon is, becauſe the inſtruments of it muſt be firm and ſtrong, and conſequently they will be too heavy to be carried by their own force; but yet (ſaith he) if it be a little helped in the firſt riſing, and if there be any wind to aſſiſt it in the flight, then there is nothing to hinder, but that ſuch motions may be poſſible. So that he doth in effect grant as much as may be ſufficient for the truth and credit of thoſe ancient relations; and to diſtruſt them without a ſtronger argument, muſt needs argue a blind and perverſe incredulity. As for his objection concerning the heavineſſe of the materials in ſuch an invention, it may be anſwered that it is eaſie to contrive ſuch ſprings and other inſtruments, whoſe ſtrength ſhall much exceed their heavineſſe. Nor can he ſhew any cauſe why theſe Mechanicall motions may not be as ſtrong, (though not ſo laſting) as the naturall ſtrength of living creatures.

Scaliger

Scaliger conceives the framing of ſuch volant *Automata*, to be very eaſie. *Volantis columbæ machinulam, cujus autorem Archytam tradunt, vel facillime profiteri audeo.* Thoſe ancient motions were thought to be contrived by the force of ſome included air: So *Gellius, Ita erat ſcilicet libramentis ſuſpenſum, & aurâ ſpiritus incluſâ atque occultâ conſitum, &c.* As if there had been ſome lamp, or other fire within it, which might produce ſuch a forcible rarefaction, as ſhould give a motion to the whole frame.

Subtil. Exercit. 326.

Noct. Attic. l. 10. cap. 12. where he thinks it ſo ſtrange an invention that he ſtyles *Res abhorrens à fide.*

But this may be better performed by the ſtrength of ſome ſuch ſpring as is commonly uſed in watches; this ſpring may bee applyed unto one wheel, which ſhall give an equall motion to both the wings; theſe wings having unto each of them another ſmaller ſpring by which they may be contracted and lifted up: So that being forcibly depreſſed by the ſtrength of the great and ſtronger ſpring, and lifted up again by the other two. According to this ſuppo-

Athan. Kircher de Magnete l. 2. par. 4. Proem: doth promiſe a large diſcourſe cōcerning theſe kind of inventions in another Treatiſe which he ſtyles *Oedipus Aegyptiacus.*

sition, it is easie to conceive how the motion of flight may be performed and continued.

The wings may be made either of *severall substances joyned*, like the feathers in ordinary fowl, as *Dædalus* is feigned to contrive them, according to that in the Poet,

Ovid. Metam. l. 8.

--Ignotas animum dimittit in artes,
Naturamque novat, nam ponit in ordine pennas
A minimo cœptas longam breviore sequente,
Vt clivo crevisse putes, &c.

Or else of *one continuate substance*, like those of Bats. In framing of both wch, the best guidance is to follow (as near as may be) the direction of nature; this being but an imitation of a naturall work. Now in both these, the strength of each part is proportioned to the force of its imployment. But nothing in this kind can be perfectly determined without a particular triall.

Though the composing of such motions may be a sufficient reward to any ones industry in the searching af-

after them, as being in themſelves of excellent curioſity; yet there are ſome other inventions depend upon them of more generall benefit and greater importance. For if there be any ſuch artificiall contrivances that can flye in the air, (as is evident from the former relations, together with the grounds here ſpecified, and I doubt not, may bee eaſily effected by a diligent and ingenious artificer) then it will clearly follow, that it is poſſible alſo for a man to fly himſelf: It being eaſie from the ſame grounds to frame an inſtrument, wherein any one may ſit, and give ſuch a motion unto it, as ſhall convey him aloft through the air. Then which there is not any imaginable invention that could prove of greater benefit to the world, or glory to the Author. And therefore it may juſtly deſerve their enquiry, who have both leiſure and means for ſuch experiments.

But in theſe practicall ſtudies, unleſſe a man be able to goe to the tryall of things, he will perform but little. In ſuch matters,

Horace. *-Studium ſine divite venâ,*

(as the Poet ſaith) a generall ſpeculation, without particular experiment, may conjecture at many things, but can certainly effect nothing. And therefore I ſhall only propoſe unto the world, the Theory and generall grounds that may conduce to the eaſie and more perfect diſcovery of the ſubject in queſtion, for the incouragement of thoſe that have both minds and means for ſuch experiments. This ſame Scholars fate,

Res anguſta domi, and
--curta ſupellex

is that which hinders the promoting of learning in ſundry particulars, and robs the world of many excellent inventions. We read of *Ariſtotle*, that he was allowed by his pupill *Alexander* 800 talents a year, for the payment of Fiſhers, Fowlers, and Hunters, who were to bring him in ſeverall creatures, that ſo by his particular experience of their parts and diſpoſitions, he might be more fitly prepared

pared to write of their natures. The reaſon why the world hath not many *Ariſtotles* is, becauſe it hath ſo few *Alexanders.*

Amongſt other impediments of any ſtrange invention or attempts, it is none of the meaneſt diſcouragements, that they are ſo generally derided by common opinion, being eſteemed only as the dreams of a melancholy & diſtempered fancy. *Euſebius* ſpeaking with what neceſſity every thing is confined by the laws of nature, and the decrees of providence, ſo that nothing can goe out of that way, unto which naturally it is deſigned; as a fiſh cannot reſide on the land, nor a man in the water, or aloft in the air, infers, that therefore none will venture upon any ſuch vain attempt, as paſſing in the air, ἢ μελαγχολίας νοσήματα ἂν περιπέσοι, unleſſe his brain be a little crazed with the humour of melancholy; whereupon he adviſes that we ſhould not in any particular endevour to tranſgreſſe the bounds of nature, ὐδὲ ἄπτερον ἔχοντα τὸ σῶμα, τὰ τῶν

Contra Hierocl. confut. l. 1.

πτηνῶν ἐπιτηδεύειν, and ſince we are naturally deſtitute of wings, not to imitate the flight of Birds. That ſaying of the Poet,

Virgil. Aeneid. l. 6.

Demens qui nimbos & non imitabile
fulmen, &c.

hath been an old cenſure applyed unto ſuch as ventured upon any ſtrange or incredible attempt.

Hence may we conceive the reaſon, why there is ſo little intimation in the writings of antiquity, concerning the poſſibility of any ſuch invention. The Ancients durſt not ſo much as mention the art of flying, but in a fable.

Dædalus, ut fama eſt, fugiens Minoia
regna,
Præpetibus pennis auſus ſe credere cælo,
Inſuetum per iter gelidas enavit ad ar-
ctos, &c.

It was the cuſtome of thoſe former ages, in their overmuch gratitude, to advance the firſt Authours of any uſefull diſcovery, amongſt the number of their gods. And *Dædalus* being ſo famous amongſt them for

ſundry

ſundry Mechanicall inventions (eſpecially the ſails of ſhips) though they did not for theſe place him in the heavens, yet they have promoted him as near as they could, feigning him to fly aloft in the air, when as he did but fly in a ſwift ſhip, as *Diodorus* relates the Hiſtoricall truth, on which that fiction is grounded. So *Euſebius* too.

CAP. VII.

Concerning the Art of flying. The ſeverall ways whereby this hath been or may be attempted.

I Have formerly in two other * Diſcourſes mentioned the poſſibility of this art of flying, and intimated a further inquiry into it, which is a kind of engagement to ſome fuller diſquiſitions and conjectures to that purpoſe.

* World in the Moon, ca 14. Mercury, or the ſecret and ſwift Meſſenger, c.4.

There are four ſeverall ways whereby this flying in the air, hath beene or may be attempted. Two of them by the ſtrength of other things, and two of them by our owne ſtrength.

1. By ſpirits or Angels.

2. By the help of fowls.

3. By wings faſtned immediately to the body.

4. By a flying chariot.

1. For the firſt, we read of divers that have paſſed ſwiftly in the air, by the help of ſpirits and Angels, whether good Angels, as * *Elias* was carried unto heaven in a fiery chariot: as † *Philip* was conveyed to *Azotus*, and *Habbacuck* from Jewry to Babylon, and back again immediately: Or by evill Angels, as our Saviour was carried by the Devill to the top of a high mountain, and to the pinacle of the Temple. Thus witches are commonly related to paſſe unto their uſuall meetings in ſome remote place; and as they doe ſell windes unto Mariners, ſo likewiſe are they ſometimes hired to carry men ſpeedily through the open air. *Acoſta* affirms that ſuch kind of paſſages are uſuall amongſt divers Sorcerers with the Indians at this day.

Zanch. de oper. pars 1. *l.* 4.

* 2 Kings 2. 11.

† Acts 8. 39.

Dan. Apoc 39.

Luke 4.

Eraſtus de Lamiis.

Hiſt. Ind. l. 5. *c.* 26.

So

So *Kepler* in his Aſtronomicall dream, doth fancy a witch to be conveyed unto the Moon by her Familiar.

Simon Magus was ſo eminent for miraculous ſorceries, that all the people in *Samaria* from the leaſt to the greateſt, did eſteem him *as the great power of God.* And ſo famous was he at *Rome*, that the Emperour erected a ſtatue to him with this inſcription, *Simoni Deo Sancto.* 'Tis ſtoried of this Magician, that having challenged Saint *Peter* to doe miracles with him, he attempted to fly from the Capitoll to the Aventine hill. But when he was in the midſt of the way, Saint *Peters* prayers did overcome his ſorceries, and violently bring him to the ground, in which fall having broke his thigh, within a while after he died.

Acts 8.10.

Hegeſip.l.3 c.2.

Pol.Virgil. de Inven. Rerum.l.8. c.3.

Pet.Crinitus de Honeſtâ Diſciplin.l 8.c. 1. miſtruſts this relation as fabulous. *Non enim Lucas hoc omiſiſſet.*

But none of all theſe relations may conduce to the diſcovery of this experiment, as it is here enquired after, upon *natural* & *artificial* grounds.

2. There are others who have con-

conjectured a possibility of being conveyed through the air by the help of fowls; to which purpose that fiction of the *Ganza's*, is the most pleasant and probable. They are supposed to be great fowl of a strong lasting flight, and easily tamable. Divers of which may be so brought up as to joyn together in carrying the weight of a man, so as each of them shall partake his proportionable share of the burden; and the person that is carried may by certain reins direct and steer them in their courses. However this may seem a strange proposall, yet it is not certainly more improbable, then many other arts, wherein the industry of ingenious men hath instructed these brute creatures. And I am very confident, that one whose genius doth enable him for such kind of experiments upon leisure, and the advantage of such helps as are requisite for various and frequent trials, might effect some strange thing by this kind of enquiry.

'Tis reported as a custome amongst the

the *Leucatians*, that they were wont upon a ſuperſtition to precipitate a man from ſome high cliffe into the ſea, tying about him with ſtrings at ſome diſtance, many great fowls, and fixing unto his body divers feathers ſpread, to break the fall; which (ſaith the learned *Bacon*, if it were diligently and exactly contrived) would be able to hold up, and carry any proportionable weight; and therefore he adviſes others to think further upon this experiment, as giving ſome light to the invention of the art of flying.

Nat. hiſt. experim. 886.

3. 'Tis the more obvious and common opinion that this may be effected by wings faſtned immediately to the body, this coming neareſt to the imitation of nature, which ſhould be obſerved in ſuch attempts as theſe. This is that way which *Fredericus Hermannus* in his little diſcourſe *de Arte volandi*, doth onely mention and inſiſt upon. And if we may truſt credible ſtory, it hath been frequently attempted not without ſome ſucceſſe.

So the ancient Britiſh Bladuds.

'Tis

'Tis related of a certaine English Munk called *Elmerus*, about the Confessors time, that he did by such wings fly from a Tower above a furlong; and so another from Saint *Marks* steeple in *Venice*; another at *Norinberge*; and *Busbequius* speaks of a Turk in *Constantinople*, who attempted something this way. M. *Burton* mentioning this quotation, doth beleeve that some new-fangled wit ('tis his cynicall phrase) will some time or other find out this art. Though the truth is, most of these Artists did unfortunately miscarry by falling down and breaking their arms or legs, yet that may be imputed to their want of experience, and too much fear, which must needs possesse men in such dangerous and strange attempts. Those things that seem very difficult and fearfull at the first, may grow very facil after frequent triall and exercise. And therefore he that would effect any thing in this kind, must be brought up to the constant practise of it from his youth. Trying

Eraestus Burgravus in Panoplia Physico-Vulcania. Sturmius in Lat: linguæ resolut.

Melancholy, *Par.* 2. *Sect.* 1. *Mem.* 3.

ing firſt onely to uſe his wings in running on the ground, as an Eſtrich or tame Geeſe will doe, touching the earth with his toes; and ſo by degrees learn to riſe higher, till hee ſhall attain unto skill and confidence. I have heard it from credible teſtimony, that one of our own Nation hath proceeded ſo far in this experiment, that he was able by the help of wings in ſuch a running pace to ſtep conſtantly ten yards at a time.

It is not more incredible that frequent practiſe and cuſtome ſhould inable a man for this, then for many other things which we ſee confirmed by experience. What ſtrange agility & activeneſſe doe our common tumblers & dancers on the rope attain to by cõtinuall exerciſe? 'Tis related of certain Indians, that they are able when a horſe is running in his full career, to ſtand upright on his back, to turn thẽſelves round, to leap down, gathering up any thing from the ground, & immediatly to leap up again, to ſhoot exactly at any mark, the horſe not inter- *Maffæus Hiſt.Ind. l.1.*

mitting

mitting his courſe. And ſo upon two horſes together, the man ſetting one of his feet upon each of them. Theſe things may ſeem impoſſible to others, and it would be very dangerous for any one to attempt them, who hath not firſt gradually attained to theſe arts, by long practiſe and triall; and why may not ſuch practiſe inable him as well for this other experiment, as for theſe things?

There are others who have invented ways to walk upon the water, as regularly and firmly as upon the land. There are ſome ſo accuſtomed to this element, that it hath been almoſt as naturall to them, as to the fiſh; men that could remain for above an hower together under water. *Pontanus* mentions one who could ſwim above a hundred miles together, from one ſhore to another, with great ſpeed, and at all times of the year. And it is ſtoried of a certain young man, a *Sicilian* by birth, and a *Diver* by profeſſion, who had ſo continually uſed himſelf to the water, that he could not

Treatiſe of cuſtome.

not enjoy his health out of it. If at any time he ſtaid with his friends on the land, he ſhould be ſo tormented with a pain in his ſtomack, that he was forced for his health to returne back again to ſea; wherein he kept his uſuall reſidence, and when hee ſaw any ſhips, his cuſtome was to ſwim to them for relief, which kind of life he continued till he was an old man, and dyed.

I mention theſe things to ſhew the great power of practiſe and cuſtome, which might more probably ſucceed in this experiment of flying (if it were but regularly attempted) then in ſuch ſtrange effects as theſe.

It is a uſuall practiſe in theſe times, for our *Funambulones*, or Dancers on the Rope, to attempt ſomewhat like to flying, when they will with their heads forwards ſlide downe a long cord extended; being faſtned at one end on the top of ſome high Tower, and the other at ſome diſtance on the ground, with wings fixed to their ſhoulders, by the ſhaking of which

they

they will break the force of their defcent. It would feem that fome attempts of this kind were ufuall amongft the *Romanes*. To which that expreffion in * *Salvian* may referre, where amongft other publike fhewes of the Theater, he mentions the *Petaminarii* : which word (faith *Jo: Brafsicanus*) is fcarce to be found in any other Authour, being not mentioned either in *Julius Pollux*, or *Politian*. 'Tis probably derived from the Greek word πέταω, which fignifies to fly, and may refer to fuch kind of Rope-dancers.

* *De guber. Dei.l.6.*

Annot. in Salvi.

But now becaufe the arms extended, are but weak and eafily wearied, therfore the motions by them are like to be but fhort and flow, anfwerable it may be to the flight of fuch domeftick fowl as are moft converfant on the ground, which of themfelves we fee are quickly weary, and therefore much more would the arm of a man, as being not naturally defigned to fuch a motion.

It were therefore worth the inquiry to conſider whether this might not be more probably effected by the labour of the feet, which are naturally more ſtrong and indefatigable: In which contrivance the wings ſhould come down from the ſhoulders on each ſide as in the other, but the motion of them ſhould be from the legs, being thruſt out and drawn in again one after another, ſo as each leg ſhould move both wings, by which means a man ſhould (as it were) walk or climbe up into the air: and then the hands and arms might be at leiſure to help and direct the motion, or for any other ſervice proportionable to their ſtrength. Which conjecture is not without good probability, and ſome ſpeciall advantages above the other.

4. But the fourth and laſt way ſeems unto me altogether as probable, and much more uſefull then any of the reſt. And that is by a flying chariot, which may be ſo contrived as to carry a man within it; & though the ſtrength of a ſpring might per-

haps be ſerviceable for the motion of this engine, yet it were better to have it aſſiſted by the labour of ſome intelligent mover as the heavenly orbs are ſuppoſed to be turned. And therefore if it were made big enough to carry ſundry perſons together, then each of them in their ſeverall turns might ſucceſſively labour in the cauſing of this motion; which thereby would be much more conſtant and laſting, then it could otherwiſe be, if it did wholly depend on the ſtrength of the ſame perſon. This contrivance being as much to be preferred before any of the other, as ſwimming in a ſhip before ſwimming in the water.

CAP. VIII.

A reſolution of the two chief difficulties that ſeem to oppoſe the poſsibility of a flying Chariot.

THe chief difficulties againſt the poſſibility of any ſuch contrivance may be fully removed in the reſolution

tion of these two *Quæres.*

1. Whether an engine of such capacity and weight, may be supported by so thin and light a body as the air?

2. Whether the strength of the persons within it, may be sufficient for the motion of it?

1. Concerning the first; when *Callias* was required by the men of *Rhodes*, to take up that great *Helepolis*, brought against them by *Demetrius*, (as he had done before unto some lesse which hee himselfe had made.) He answered that it could not be done. *Nonnulla enim sunt quæ in exemplaribus videntur similia, cum autem crescere cæperunt, dilabuntur.* Because those things that appear probable in lesser models, when they are increased to a greater proportion, doe thereby exceed the power of art. For example, though a man may make an instrument to bore a hole, an inch wide, or half an inch, and so lesse; yet to bore a hole of a foot wide, or two foot, is not so much as to bee

Vitruvius Archit.l.10 c.22.

So *Ramus Schol. Mathem.l.1.*

thought of. Thus, though the air may be able to uphold ſome leſſer bodies, as thoſe of birds, yet when the quantity of them is increaſed to any great extenſion, it may juſtly be doubted, whether they will not exceed the proportion that is naturally required unto ſuch kind of bodies.

To this I anſwer, that the engine can never be too big or too heavy, if the ſpace which it poſſeſſes in the air, and the motive faculty in the inſtrument be anſwerable to its weight. That ſaying of *Callias* was but a groundleſſe ſhift and evaſion, wherby hee did endeavour to palliate his own ignorance and diſability. The utmoſt truth which ſeems to be implyed in it, is this: That there may be ſome bodies of ſo great a bigneſſe, & gravity, that it is very difficult to apply ſo much force unto any particular inſtrument, as ſhall be able to move them.

Againſt the example it may be affirmed and eaſily proved, that it is equally poſſible to bore a hole of any bigneſſe,

bigneſſe, as well great as little, if we ſuppoſe the inſtrument, & the ſtrength and the application of this ſtrength to be proportionable; But becauſe of the difficulty of theſe concurrent circumſtances in thoſe greater and more unuſuall operations, therefore doe they falſly ſeem to be abſolutely impoſſible.

So that the chief inference from this argument and example, doth imply onely thus much, that it is very difficult to contrive any ſuch motive power, as ſhall be anſwerable to the greatneſſe and weight of ſuch an inſtrument as is here diſcourſed of, which doth not at all impair the truth to be maintained; For if the poſſibility of ſuch a motion be yeelded, we need not make any ſcruple of granting the difficultie of it; It is this muſt adde a glory to the invention; and yet this will not perhaps ſeem ſo very difficult to any one who hath but diligently obſerved the flight of ſome other birds, particularly of a Kite, how he will ſwim up and down in the air, ſometimes at a great height, and preſently again lower, guiding himſelf by his train, with his wings extended without any ſenſible motion of them; and all this, when there is only ſome gentle breath of air ſtirring, without the help of any ſtrong forcible wind. Now I ſay, if that fowl (which is none of the lighteſt) can ſo very eaſily move it ſelf up and down in the air, without ſo much as ſtirring the wings of it: certainely then, it is not improbable, but that when all the due proportions in ſuch an engine are found out, and when men by long practiſe have arrived to any skill and experience, they will be able in this (as well as in many other things) to come very near unto the imitation of nature.

As it is in thoſe bodies which are carried on the water, though they be never ſo bigge or ſo ponderous, (ſuppoſe equall to a City or a whole Iſland) yet they will alwaies ſwim on the top, if they be but any thing lighter, then ſo much water

Sen. Nat. Qu. l. 3. c. 25.

as

as is equall to them in bignesse: So likewise is it in the bodies that are carried in the air. It is not their greatnesse (though never so immense) that can hinder their being supported in that light element, if we suppose them to be extended unto a proportionable space of air. And as from the former experiments, *Archimedes* hath composed a subtle *science* in his Book, *De insidentibus humido*, concerning the weight of any heavy body, in reference to the water wherein it is: So from the particular triall of these other experiments, that are here inquired after, it is possible to raise a new science, concerning the extension of bodies, in comparison to the air, and motive faculties by which they are to be carried.

We see a great difference betwixt the severall quantities of such bodies, as are commonly upheld by the air; not only little gnats, & flies, but also the Eagle and other fowl of vaster magnitude. *Cardan* and *Scaliger* doe unanimously affirm, that there is a bird

Subtil.l.10. Exercit. 231.

bird amongst the Indians of so great a bignesse, that his beak is often used to make a sheath or scabbard for a sword. And *Acosta* tels us of a fowl in *Peru* called *Condores*, which will of themselves kill and eat up a whole Calf at a time. Nor is there any reason why any other body may not be supported and carried by the air, though it should as much exceed the quantity of these fowl, as they doe the quantity of a flie.

Histor. Nov. Orb. l. 4. c. 37.

Marcus Polus mentions a fowl in *Madagascar*, which he cals a *Ruck*, the feathers of whose wings are 12 paces, or threescore foot long, which can with as much ease, soop up an Elephant, as our Kites doe a Mouse. If this relation were any thing credible, it might serve as an abundant proof for the present quære. But I conceive this to be already so evident, that it needs not any fable for its further confirmation.

2. The other doubt was, whether the strength of the other persons within it, will be sufficient for the

moving

moving of this engine? I anſwer, the main difficulty and labour of it will be in the raiſing of it from the ground; neer unto which, the earths attractive vigor, is of greateſt efficacy. But for the better effecting of this, it may be helped by the ſtrength of winds, and by taking its firſt riſe from ſome mountain or other high place. When once it is aloft in the air, the motion of it will be eaſie, as it is in the flight of all kind of birds, which being at any great diſtance from the earth, are able to continue their motion for a long time & way, with little labour or wearineſſe.

'Tis certain from common relation and experience that many birds doe croſs the ſeas for divers hundred miles together: ſundry of them amongſt us, which are of a ſhort wing and flight, as Blackbirds, Nightingales, &c. doe flie from us into *Germany*, and other remoter Countries. And Mariners doe commonly affirm that they have found ſome fowle above ſixe hundred miles from any land. Now

*Plin.l.*10. *c.*23.

Now if we ſhould ſuppoſe theſe birds to labour ſo much in thoſe long journies, as they doe when they flie in our ſight and near the earth, it were impoſſible for any of them to paſſe ſo farre without reſting. And therefore it is probable, that they do mount unto ſo a high a place in the air, where the naturall heavineſſe of their bodies does prove but little or no impediment to their flight; Though perhaps either hunger, or the ſight of ſhips, or the like accident, may ſometimes occaſion their deſcending lower, as we may gheſſe of thoſe birds, which Mariners have thus beheld, and divers others that have been drowned and caſt up by the ſea.

Whence it may appear, that the motion of this chariot (though it may be difficult at the firſt) yet will ſtill be eaſier as it aſcends higher, till at length it ſhall become utterly devoid of gravity, when the leaſt ſtrength will be able to beſtow upon it a ſwift motion: as I have proved more

more at large in another diſcourſe. World in the Moon, c.14.

But then, (may ſome object) If it be ſuppoſed that a man in the æthereall air does loſe his own heavineſſe, how ſhall he contribute any force towards the motion of this inſtrument?

I anſwer, The ſtrength of any living creature in theſe externall motions, is ſomething really diſtinct from, and ſuperadded unto its naturall gravity: as common experience may ſhew, not only in the impreſſion of blows or violent motions, as a river hawk will ſtrike a fowl with a far greater force, then the meer deſcent or heavineſſe of his body could poſſibly perform. But alſo in thoſe actions which are done without ſuch help, as the pinching of the finger, the biting of the teeth,&c. all which are of much greater ſtrength then can proceed from the meer heavines of thoſe parts.

As for the other particular doubts, concerning the extream thinneſſe, and coldneſſe of this æthereall air, by reaſon of which, it may ſeem to be al-

altogether impaſſible, I have already reſolved them in the above cited diſcourſe.

The uſes of ſuch a Chariot may be various: beſides the diſcoveries which might be thereby made in the lunary world; It would be ſerviceable alſo for the conveyance of a man to any remote place of this earth: as ſuppoſe to the *Indies* or *Antipodes*. For when once it was elevated for ſome few miles, ſo as to be above that orb of magnetick virtue, which is carried about by the earths diurnall revolution, it might then be very eaſily and ſpeedily directed to any particular place of this great globe.

If the place which we intended were under the ſame parallel, why then the earths revolution once in 24 howers, would bring it to be under us, ſo that it would be but deſcending in a ſtraight line, and wee might preſently be there. If it were under any other parallel, it would then only require that we ſhould direct it in the ſame Meridian, til we did come to that paral-

parallel; and then (as before) a man might eaſily deſcend unto it.

It would be one great advantage in this kind of travelling, that one ſhould be perfectly freed from all inconveniences of ways or weather, not having any extremity of heat, or cold, or Tempeſts to moleſt him. This æthereall air being perpetually in an equall temper and calmneſſe. *Pars ſuperior mundi ordinatior eſt nec in nubem cogitur, nec in tempeſtatem impellitur, nec verſatur in turbinem, omni tumultu caret, inferiora fulminant.* The upper parts of the world are always quiet and ſerene, no winds and bluſtring there, they are theſe lower clowdy regions that are ſo full of tempeſts and combuſtion.

Sen. de Irâ l.3.c.6. Pacem ſumma tenent. Lucan.

As for the manner how the force of a ſpring, or (in ſtead of that) the ſtrength of any living perſon, may bee applyed to the motion of theſe wings of the Chariot, it may eaſily be apprehended from what was formerly delivered.

There are divers other particulars

to be more fully enquired after, for the perfecting of ſuch a flying Chariot; as concerning the proportion of the wings both for their length and breadth, in compariſon to the weight which is to bee carried by them, as alſo concerning thoſe ſpeciall contrivances, whereby the ſtrength of theſe wings may be ſeverally applyed either to aſcent, deſcent, progreſſive, or a turning motion; All which, and divers the like enquiries can onely be reſolved by particular experiments. We know the invention of ſayling in ſhips does continually receive ſome new addition from the experience of every age, and hath been a long while growing up to that perfection, unto which it is now arrived. And ſo muſt it be expected for this likewiſe, which may at firſt perhaps ſeeme perplexed with many difficulties and inconveniences, and yet upon the experience of frequent tryals, many things may be ſuggeſted to make it more facil and commodious.

As well too long as too ſhort, too broad as too narrow, may be an impediment to the motion, by making it more difficult, ſlow and flagging.

He

He that would regularly attempt any thing to this purpose, should observe this progresse in his experiments,he should first make enquiry what kind of wings would bee most usefull to this end; those of a Bat being most easily imitable, and perhaps nature did by them purposely intend some intimation to direct us in such experiments; that creature being not properly a bird, because not amongst the *Oviparas*, to imply that other kind of creatures are capable of flying as well as birds, and if any should attempt it, that would be the best pattern for imitation.

After this he might try what may be effected by the force of springs in lesser models, answerable unto *Archytas* his Dove,and *Regiomontanus* his Eagle: In which he must be carefull to observe the various proportions betwixt the strength of the spring,the heavinesse of the body, the breadth of the wings, the swiftnesse of the motion, &c.

From these he may by degrees ascend to some larger essays. CAP.

CAP. IX.

Of a perpetuall motion. The ſeeming facility and reall difficulty of any ſuch contrivance. The ſeverall ways whereby it hath been attempted, particularly by Chymiſtry.

IT is the chief inconvenience of all the *Automata* before mentioned, that they need a frequent repair of new ſtrength, the cauſes whence their motion does proceed, being ſubject to fail and come to a period; and therefore it would be worth our enquiry, to examine, whether or no there may be made any ſuch artificiall contrivance, which might have the principle of moving from it ſelf: ſo that the preſent motion ſhould conſtantly be the cauſe of that which ſucceeds.

This is that great ſecret in *art*, which like the Philoſophers ſtone in *nature*, hath been the buſineſſe and ſtudy of many more refined wits, for divers ages together; and it may well be queſtioned, whether either

of

of them as yet, hath ever beene found out, though if this have, yet like the other, it is not plainly treated of by any Authour.

Not but that there are ſundry diſcourſes concerning this ſubject, but they are rather *conjectures* then *experiments*. And though many inventions in this kind, may at firſt view bear a great ſhew of probability, yet they will fail being brought to triall, and will not anſwer in practiſe what they promiſed in ſpeculation. Any one who hath beene verſed in theſe experiments muſt needs acknowledge that hee hath been often deceived in his ſtrongeſt confidence; when the imagination hath contrived the whole frame of ſuch an inſtrument, and conceives that the event muſt infallibly anſwer its hopes; yet then, does it ſtrangely deceive in the proof, and diſcovers to us ſome defect, which we did not before take notice of.

Hence is it, that you ſhall ſcarce talk with any one who hath never ſo little ſmattering in theſe arts, but he

 will

will inſtantly promiſe ſuch a motion, as being but an eaſie atchievement, till further triall and experience hath taught him the difficulty of it. There being no enquiry that does more entice with the *probability*, and deceive with the *ſubtilty*. What one ſpeakes wittily concerning the Philoſophers ſtone, may be juſtly applyed to this, that it is *Caſta meretrix*, a chaſte whore. *Quia multos invitat, neminem admittit*, becauſe it allures many, but admits none.

I ſhall briefly recite the ſeverall ways whereby this hath been attempted, or ſeems moſt likely to be effected, thereby to contract and facilitate the enquiries of thoſe who are addicted to theſe kind of experiments; for when they know the defects of other inventions, they may the more eaſily avoid the ſame, or the like in their own.

The ways whereby this hath been attempted, may be generally reduced to theſe three kinds:

1. By Chymicall extractions.

2. By Magneticall virtues.

3. By the naturall affection of gravity.

1. The discovery of this hath been attempted by Chymistry. *Paracelsus* and his followers have bragged, that by their separations and extractions, they can make a little world which shall have the same perpetuall motions with this *Microcosme*, with the representation of all Meteors, Thunder, snow, rain, the courses of the sea in its ebbs and flows, and the like; But these miraculous promises would require as great a faith to beleeve them, as a power to perform them: And though they often talk of such great matters,

> *At nusquam totos inter qui talia curant,*
> *Apparet ullus, qui re miracula tanta*
> *Comprobet--*

yet we can never see them confirmed by any reall experiment; and then besides, every particular Authour in that art, hath such a distinct language of his own, (all of them being so full of allegories and affected obſcurities) that 'tis very hard for any one (unleſſe hee bee throughly verſed amongſt them) to finde out what they mean, much more to try it.

Etten. Mathem. Recreat. prob. 118.

One of theſe ways (as I finde it ſet down) is this. Mixe five ounces of ☿, with an equall weight of ♃, grinde them together with ten ounces of ſublimate, diſſolve them in a Cellar upon ſome marble for the ſpace of four days, till they become like oyl olive; diſtill this with fire of chaffe, or driving fire, and it will ſublime into a dry ſubſtance: and ſo by repeating of theſe diſſolvings and diſtillings, there will bee at length produced divers ſmall atomes, which being put into a glaſſe well luted, and kept dry, will have a perpetuall motion.

I cannot ſay any thing from experience againſt this; but me thinks it does not ſeem very probable, becauſe things that are forced up to ſuch a vigorouſneſſe and activity, as theſe ingredients ſeem to be by their frequent

quent ſublimatings and diſtillings, are not likely to be of any duration; the more any thing is ſtretched beyond its uſualll nature, the leſſe does it laſt, violence and perpetuity being no companions. And then beſides, ſuppoſe it true, yet ſuch a motion could not well be applied to any uſe, which muſt needs take much from the delight of it.

Amongſt the Chymicall experiments to this purpoſe, may be reckoned up that famous motion invented by *Cornelius Dreble*, and made for King *James*; wherein was repreſented the conſtant revolutions of the Sun and Moone, and that without the help either of ſpring or weights. *Marcellus Vranckhein*, ſpeaking of the means whereby it was performed, he cals it, *Scintillula animæ magneticæ mundi, ſeu Aſtralis & inſenſibilis ſpiritus*; being that grand ſecret, for the diſcovery of which, thoſe Dictators of Philoſophie, *Democritus*, *Pythagoras*, *Plato*, did travell unto the Gymnoſophiſts, and Indian Prieſts.

Celebrated in an Epigram by *Hugo Grotius. l.1. Epi. Epiſt. ad Erneſtũ de Lamp: Vitæ.*

Epist. ad Iacobum Regem.

The Authour himſelf in his diſcourſe upon it, does not at all reveal the way, how it was performed. But there is one *Thomas Tymme*, who was a familiar acquaintance of his, and did often pry into his works, (as he profeſſes himſelf) who affirms it to bee done thus; *By extracting a fiery ſpirit out of the Minerall matter, joyning the ſame with his proper aire, which included in the Axle tree* (of the firſt moving wheel) *being hollow, carrieth the other wheels, making a continuall rotation, except iſſue or vent bee given in this hollow axle tree, whereby the impriſoned ſpirit may get forth.*

Philoſophicall dialogue. *Confer.* 2. *cap.* 3.

What ſtrange things may be done by ſuch extractions, I know not, and therefore dare not condemn this relation as impoſſible; but me thinks it ſounds rather like a chymicall dream, then a Philoſophicall truth. It ſeems this impriſoned ſpirit is now ſet at liberty, or elſe is grown weary, for the inſtrument (as I have heard) hath ſtood ſtill for many years. It is here conſiderable that any force is weakeſt

near

near the center of a wheel; and therefore though ſuch a ſpirit might of it ſelf have an agitation, yet 'tis not eaſily conceivable how it ſhould have ſtrength enough to carry the wheels about with it. And then the abſurdity of the Authours citing this, would make one miſtruſt his miſtake; he urges it as a ſtrong argument againſt *Copernicus*, as it becauſe *Dreble* did thus contrive in an Engine, the revolution of the heavens, and the immoveableneſſe of the earth, therefore it muſt needs follow that 'tis the heavens which are moved, and not the earth. If his relation were no truer then his conſequence, it had not been worth the citing.

Cap. X.

Of ſubterraneous lamps, divers hiſtoricall relations concerning their duration for many hundred yeares together.

UNto this kind of Chymicall experiments, wee may moſt probably reduce thoſe perpetuall lamps, which for many hundred yeares together have continued burning without any new ſupply in the ſepulchres of the Ancients, and might (for ought wee know) have remained ſo for ever. All fire, and eſpecially flame, being of an active and ſtirring nature, it cannot therefore ſubſiſt without motion; whence it may ſeem, that this great enquiry hath been this way accompliſhed: and therefore it will be worth our examination to ſearch further into the particulars that concern this experiment. Though it be not ſo proper to the chief purpoſe of this diſcourſe, which concerns *Mechanicall Geometry*, yet the ſubtilty and

and curiosity of it, may abundantly require the impertinency.

There are sundry Authours, who treat of this subject on the by, and in some particular passages, but none that I know of (except *Fortunius Licetus*) that hath writ purposely any set and large discourse concerning it: out of whom I shall borrow many of those relations and opinions, which may most naturally conduce to the present enquiry.

Lib. de reconditis antiquorum lucernis.

For our fuller understanding of this, there are these particulars to be explained:

1. ὅτι, or *quod sit.*
2. διότι { *cur sit.* / *quomodo sit.* }

1. First then, for the ὅτι, or that there have been such lamps, it may be evident from sundry plaine and undeniable testimonies: Saint *Austin* mentions one of them in a Temple dedicated to *Venus*, which was always exposed to the open weather, and could never be consumed or extinguished. To him assents the judicious

De civitat. Dei l. 21. c. 6.

De operibus Dei, pars 1. l. 4. c. 12.
De deperd. Tit. 35.
* Or *Antioch. Licetus de Lucernis, l. 1. c. 7.*

ous *Zanchy*. *Pancyrollus* mentions a Lamp found in his time, in the ſepulchre of *Tullia*, *Cicero's* daughter, which had continued there for about 1550 years, but was preſently extinguiſhed upon the admiſſion of new air. And 'tis commonly related of *Cedrenus*, that in *Juſtinians* time there was another burning lamp found in an old wall at * *Edeſſa*, which had remained ſo for above 500 years, there being a crucifixe placed by it, whence it ſhould ſeem, that they were in uſe alſo amongſt ſome Chriſtians.

But more eſpecially remarkable, is that relation celebrated by ſo many Authours, concerning *Olybius* his lamp, which had continued burning for 1500 years. The ſtory is thus: As a ruſtick was digging the ground by *Padua*, he found an Urne or earthen pot, in which there was another urne, and in this leſſer, a lamp clearly burning; on each ſide of it, there were two other Veſſels, each of them full of a pure liquor, the one of gold, the other of ſilver. *Ego Chymiæ artis*, (*ſi modo*

modo vera poteſt eſſe ars Chymia) jurare auſim elementa & materiam omnium, (ſaith *Maturantius,* who had the poſſeſſion of theſe things after they were taken up.) On the bigger of theſe urns there was this inſcription:

Plutoni ſacrum munus ne attingite fures,
Ignotū eſt vobis hoc quod in orbe latet,
Namque elementa gravi clauſit digeſta labore
Vaſe ſub hoc modico, Maximus Olybius.
Adſit fœcundo cuſtos ſibi copia cornu,
Ne tanti pretium depereat laticis.

The leſſer urn was thus inſcribed:

Abite hinc peßimi fures,
Vos quid vultis, veſtris cum oculis emißitiis?
Abite hinc, veſtro cum Mercurio
Petaſato Caduceatoque,
Donum hoc Maximum, Maximus Olybius
Plutoni ſacrum facit.

Whence wee may probably conjecture that it was ſome Chymicall ſecret,

cret, by which this was contrived.

Mag. Natural. l.12. cap. ult.

Baptista Porta tels us of another lamp burning in an old marble sepulchre, belonging to some of the ancient Romans, inclosed in a glasse viall, found in his time, about the year 1550, in the Isle *Nesis*, which had been buried there before our Saviours coming.

Chron. Martin. Fort. Licet. de lucern. l.1.c.11.

In the Tombe of *Pallas*, the Arcadian who was slain by *Turnus* in the Trojan war, there was found another burning lamp, in the year of our Lord 1401. Whence it should seem, that it had continued there for above two thousand and six hundred years: and being taken out, it did remain burning, notwithstanding either wind or water, with which some did strive to quench it; nor could it be extinguished till they had spilt the liquor that was in it.

Not: ad August: de civit. Dei, l.21.c.6.

Ludovicus Vives tels us of another lamp that did continue burning for 1050 years, which was found a little before his time.

Such a lamp is likewise related to be

be ſeen in the ſepulchre of *Francis Roſicroſſe*, as is more largely expreſſed in the confeſſion of that fraternity.

There is another relation of a certain man, who upon occaſion digging ſomewhat deep in the ground, did meet with ſomething like a dore, having a wall on each hand of it, from which having cleared the earth, he forced open this dore, upon this there was diſcovered a faire Vault, and towards the further ſide of it, the ſtatue of a man in Armour, ſitting by a table, leaning upon his left arm, and holding a ſcepter in his right hand, with a lamp burning before him; the floor of this Vault being ſo contrived, that upon the firſt ſtep into it, the ſtatue would erect it ſelf from its leaning poſture; upon the ſecond ſtep it did lift up the ſcepter to ſtrike, and before a man could approach near enough to take hold of the lamp, the ſtatue did ſtrike and break it to peeces: ſuch care was there taken that it might not be ſtoln away, or diſcovered.

Our learned *Cambden* in his deſcrip- *Pag.572.*
tion

tion of *Yorkshire*, speaking of the tombe of *Constantius Chlorus*, broken up in these later years, mentions such a lamp to be found within it.

There are sundry other relations to this purpose. *Quod ad lucernas attinet, illæ in omnibus fere monumentis inveniuntur*, (saith *Gutherius.*) In most of the ancient Monuments there is some kind of lamp, (though of the ordinary sort;) But those persons who were of greatest note and wisdome, did procure such as might last without supply, for so many ages together. *Pancirollus* tels us that it was usuall for the Nobles amongst the Romans, to take speciall care in their last wils, that they might have a lamp in their Monuments. And to this purpose they did usually give liberty unto some of their slaves on this condition, that they should be watchfull in maintaining and preserving it. From all which relations, the first particular of this enquiry, concerning the beeing or existence of such lamps, may sufficiently appear.

De jure manium, l. 2. c. 32.

Deperdit. Tit. 62.

CAP.

CAP. XI.

Severall opinions concerning the nature and reason of these perpetuall Lamps.

THere are two opinions to be answered, which doe utterly overthrow the chiefe consequence from these relations.

1. Some think that these lights so often discovered in the ancient tombs, were not fire or flame, but only some of those bright bodies which do usually shine in dark places.

2. Others grant them to be fire, but yet think them to be then first enkindled by the admission of new air, when these sepulchres were opened.

1. There are divers bodies (saith *Aristotle*) which shine in the dark, as rotten wood, the scales of some fishes, stones, the glow-worm, the eyes of divers creatures. *Cardan* tels us of a bird in new *Spain*, called *Cocoyum*, whose whole body is very bright, but his eyes almost equall to the light of a

De anima, l 2.c.7.

Subtil l.9.

a candle, by which alone in a darke night, one may both write and read; By these the Indians (saith he) use to eat their feasting Suppers.

It is commonly related and beleeved, that a Carbuncle does shine in the dark like a burning coal, from whence it hath its * name. To which purpose there is a story in *Ælian*, of a Stork, that by a certain woman was cured of a broken thigh, in gratitude to whom, this fowl afterwards flying by her, did let fall into her lap a bright Carbuncle, which (saith he) would in the night time shine as clear as a lamp. But this and the like old relations are now generally disbeleeved and rejected by learned men: *Doctissimorum omnium consensu, hujusmodi gemmæ non inveniuntur*, (saith *Boetius de Boot*) a man very much skilled in, and inquisitive after such matters; nor is there any one of name that does from his own eye-sight or experience, affirm the reall existence of any gem so qualified.

* *Carlo Pyropus. Historia Animal. l.* 8

De Lapid. & Gemmis. l. 2. *c.* 8.

Some have thought that the light

in ancient tombs hath been occasioned from some such bodies as these. For if there had been any possibility to preserve fire so long a space, 'tis likely then that the *Israelites* would have known the way, who were to keep it perpetually for their sacrifices.

Vide Licet. de lucern. l. 2.

But to this opinion it might bee replyed, that none of these *Noctiluca*, or night-shining bodies have been observed in any of the ancient sepulchres, and therefore this is a mere imaginary conjecture; And then besides, some of these lamps have been taken out burning, and continued so for a considerable space afterwards. As for the supposed conveniency of them, for the perpetuating of the holy fire amongst the Jews, it may as well be feared lest these should have occasioned their idolatry; unto which that nation was so strongly addicted, upon every sleight occasion; nor may it seem strange, if the providence of God should rather permit this fire sometimes to goe out, that so by their earnest prayers, being a-

* Levit. 9. 24. 2 Chron. 7. 1. 1 King. 18. 38.

De jure Mani. l. 2. c. 32.

gain renued from heaven, (as it * somtimes was) the peoples faith might be the better stirred up and strengthned, by such frequent miracles.

2. It is the opinion of *Gutherius*, that these lamps have not continued burning for so long a space, as they are supposed in the former relations, but that they were then first enflamed by the admission of new air, or such other occasion, when the sepulchres were opened: as we see in those fat earthy vapours of divers sorts, which are oftentimes enkindled into a flame. And 'tis said, that there are some Chymicall ways, whereby iron may be so heated, that being closely luted in a glasse, it shall constantly retain the fire for any space of time, though it were for a thousand years or more; at the end of which, if the glasse be opened, and the fresh aire admitted, the iron shall be as red hot as if it were newly taken out of the fire.

But for answer to this opinion, 'tis considerable that some urns have had inscrip-

inſcriptions on them, expreſſing that the lamps within them were burning, when they were firſt buried. To which may be added the experience of thoſe which have continued ſo, for a good ſpace afterwards; whereas the inflammation of fat and viſcous vapours does preſently vaniſh. The lamp which was found in the Iſle *Neſis*, did burn clearly while it was incloſed in the glaſſe, but that being broken, was preſently extinguiſhed. As for that Chymicall relation, it may rather ſerve to prove, that fire may continue ſo many ages, without conſuming any fewell.

So that notwithſtanding the oppoſite opinions, yet 'tis more probable that there have been ſuch lamps, as have *remained burning*, without any new ſupply, for many hundred years together; which was the firſt particular to be explained.

2. Concerning the reaſon, why the Ancients were ſo carefull in this particular, there are divers opinions. Some think it to be an expreſſion of *Cur ſint.*

 their

their beleef, concerning the ſouls immortality, after its departure out of the body, a lamp amongſt the *Egyptians* being the *Hieroglyphick* of life. And therefore they that could not procure ſuch lamps, were yet carefull to have the image and repreſentation of them ingraved on their Tombes.

Others conceive them to be by way of gratitude to thoſe infernall deities, who tooke the charge and cuſtody of their dead bodies, *remaining* always with them in their Tombs, and were therefore called *Dii manes*.

Others are of opinion, that theſe lamps were onely intended to make their ſepulchres more pleaſant and lightſome, that they might not ſeem to be impriſoned in a diſmall and uncomfortable place. True indeed, the dead bodie cannot be ſenſible of this light, no more could it of its want of buriall; yet the ſame inſtinct which did excite it to the deſire of one, did alſo occaſion the other.

De Lucernis, l.3.c.8.

Licetus concludes this ancient cuſtome to have a double end. 1. *Politick,*

litick, for the diſtinction of ſuch as were nobly born, in whoſe monuments only they were uſed. 2. *Naturall*, to preſerve the body and ſoul from darkneſſe; For it was a common opinion amongſt them, that the ſouls alſo were much converſant about thoſe places where the bodies were buried.

CAP. XII.

The moſt probable conjecture how theſe lamps were framed.

THe greateſt difficulty of this enquiry doth conſiſt in this laſt particular, concerning the manner how, or by what poſſible means any ſuch perpetuall flame may be contrived. *Quomodo ſint.*

For the diſcovery of which, there are two things to be more eſpecially conſidered.

1. The ſnuffe or wiek, which muſt adminiſter unto the flame.

2. The oyl, which muſt nouriſh it.

For the firſt, it is generally granted that there are divers ſubſtances which will retain fire without conſuming: ſuch is that minerall wch they call the Salamanders wool, ſaith our learned * *Bacon. Ipſe expertus ſum villos Salamandræ non conſumi,* ſaith † *Joachimus Fortius.* And * *Wecker* from his own knowledge affirms the ſame of *plumeallum*, that being formed into the likeneſſe of a wiek, will adminiſter to the flame, and yet not conſume it ſelf. Of this nature likewiſe was that which the Ancients did call *linum vivum*, or *asbeſtinum*: of this they were wont to make garments, that were not deſtroyed, but purified by fire; and whereas the ſpots or foulneſſe of other cloaths are waſhed out, in theſe they were uſually burnt away. The bodies of the ancient Kings were wrapped in ſuch garments when they were put in the funerall pile, that their aſhes might bee therein preſerved, without the mixture of any other. The materials of them were not from any hearb or vegetable.

* *Nat. hiſt. exper.* 774.
† *Lib. exper.*
* *De Secretis, l.* 3. *c.* 2.

Or *Linum Carpaſium. Plutarch, de Oracul. defectu.*

Plin. Hiſt. l. 19. *c.* 1.

ble, as other textils, but from a stone called *Amiantus*, which being bruised by a hammer, and its earthy nature shaken out, retains certain hairy substances, which may be spun and woven as hemp or flaxe. *Pliny* says, that for the preciousnesse of it, it did almost equall the price of pearls. *Pancirollus* tels us, that it was very rare and esteemed precious in ancient times, but now is scarce found or known in any places, and therefore he reckons it amongst the things that are lost. But *L. Vives* affirms, that he hath often seen wieks made of it at *Paris*, and the same matter woven into a napkin at *Lovaine*, which was cleansed by being burnt in the fire.

Deperd. Tit.4.

In August. de civit. Dei, l.21. c.6.

'Tis probable from these various relations, that there was severall sorts of it, some of a more precious, other of a baser kinde, that was found in *Cyprus*, the deserts of *India*, and a certain Province of *Asia*: this being common in some parts of *Italy*, but is so short and brittle, that it cannot be spun into a thred. And therefore is usefull only for the wieks of perpetuall lamps, saith *Boetius de Boot*. Some of this, or very like it, I have upon inquiry lately procured and experimented. But whether it be the stone *Asbestus*, or only *plume-allum*, I cannot certainly affirm. For it seems they are both so very like, as to be commonly sold for one another (saith the same Authour.) However it does truly agree in this common quality ascribed unto both, of being incombustible, and not consumable by fire: But yet there is this inconvenience, that it doth contract so much fuliginous matter from the earthy parts of the oyl, (though it was tryed with some of the purest oyl, which is ordinary to be bought) that in a very few days it did choak and extinguish the flame. There may possibly be some chymicall way so to purifie and defecate this oyl, that it shall not spend into a sooty matter.

D lapid. et gemmis, l.2.c.204.

However if the liquour be of a close and glutinous consistency, it may burn without any snuffe, as we see in in Camphire, and ſome other bituminous ſubſtances. And it is probable that moſt of the ancient lamps were of this kind, becauſe the exacteſt relations (to my remembrance) doe not mention any that have been found with ſuch wieks.

But herein will conſiſt the greateſt difficulty, to find out what invention there might be for their duration. Concerning which there are ſundry opinions.

Saint *Auſtin* ſpeaking of that lamp in one of the Heathen Temples, thinks that it might either be done by Magick, the Devill thinking thereby to promote the worſhip and eſteem of that idoll to which it was dedicated, or elſe that the art of man might make it of ſome ſuch materiall, as the ſtone *Asbeſtus*, which being once enkindled, will burn without being conſumed. As others (ſaith he) have contrived as great a wonder in appearance, from the naturall virtue of another ſtone, making an iron image ſeem to hang in the air, by rea-

De civ. Dei l. 21. c. 6.

Zanch. de Operibus Dei, par. 1. l. 4. c. 12.

reaſon of two load-ſtones, the one being placed in the ſeeling, the other in the floor.

Others are of opinion that this may be effected in a hollow veſſell, exactly luted or ſtopped up in all the vents of it. And then, if a lamp be ſuppoſed to burn in it, but for the leaſt moment of time, it muſt continue ſo always, or elſe there would be a *Vacuū*, which nature is not capable of; If you ask, how it ſhall be nouriſhed, it is anſwered, that the oyl of it being turned into ſmoak & vapours, will again be converted into its former nature; For otherwiſe, if it ſhould remaine rarified in ſo thin a ſubſtance, then there would not be room enough for that fume which muſt ſucceed it; and ſo on the other ſide, there might bee ſome danger of the *penetration* of bodies, which nature doth as much abhor. To prevent both which, as it is in the chymicall circulations, where the ſame body is oftentimes turned from liquour into vapour, and from vapour into liquour again; ſo

in

in this experiment, the ſame oyl ſhall be turned into fume, and that fume ſhall again convert into oyl. Always provided, that this oyl which nouriſhes the lamp, bee ſuppoſed of ſo cloſe and tenacious a ſubſtance, that may ſlowly evaporate, and ſo there will be the more leiſure for nature to perfect theſe circulations. According to which contrivance, the lamp within this veſſell can never fail, being always ſupplyed with ſufficient nouriſhment. That which was found in the Iſle *Neſis*, incloſed in a glaſſe viall, mentioned by *Baptiſta Porta*, is thought to be made after ſome ſuch manner as this.

Others conceive it poſſible to extract ſuch an oyl out of ſome minerals, which ſhall for a long ſpace ſerve to nouriſh the flame of a lamp with very little or no expence of its own ſubſtance. To which purpoſe (ſay they) if gold be diſſolved into an unctuous humour, or if the radicall moiſture of that metall were ſeparated, it might be contrived to burne (perhaps

Wolphang. Lazius, l.3 c.18. Camb. Brit. p.572.

(perhaps for ever, or at leaſt) for many ages together, without being conſumed. For if gold it ſelf (as experience ſhews) be ſo untameable by the fire, that after many meltings, and violent heats, it does ſcarce diminiſh, 'tis probable then, that being diſſolved into an oylie ſubſtance, it might for many hundred years together continue burning.

There is a little chymical diſcourſe, to prove that *Vrim* and *Thummim* is to be made by art; the Authour of this Treatiſe affirms that place, *Gen.* 6.16. where God tels *Noah, a window ſhalt thou make in the Ark*, to be very unfitly rendred in our tranſlation a window, becauſe the original word צהר ſignifies properly ſplendor or light; and then beſides, the air being at that time ſo extreamely darkned with the clouds of that exceſſive rain, a window could be but of very little uſe in regard of light, unleſſe there were ſome other help for it; From whence he conjectures that both this ſplendor, and ſo likewiſe the Urim

and

and Thummim were artificiall, chymicall preparations of light, answerable to these subterraneous lamps; or in his own phrase, it was *the universall spirit fixed in a transparent body.*

It is the opinion of *Licetus* (who hath more exactly searched into the subtilties of this inquiry) that fire does not need any humour for the nourishment of it, but onely to detain it from flying upwards. For being it self one of the chief elements (saith he out of *Theophrastus*) it were absurd to think that it could not subsist without something to feed it. As for that substance which is consumed by it, this cannot be said to foment or preserve the same fire, but onely to generate new. For the better understanding of this, we must observe, that there may be a threefold proportion betwixt fire, and the humour or matter of it. Either the humour does exceed the strength of the fire, or the fire does exceed the humour; and according to both these, the flame doth presently vanish. Or else

De Lucernis, c. 20, 21

elſe laſtly, they may be both equall in their virtues, (as it is betwixt the radicall moiſture and naturall heat in living creatures) and then neither of them can overcome or deſtroy the other.

Thoſe ancient lamps of ſuch long duration were of this later kind. But now, becauſe the qualities of heat or cold, drineſſe or moiſture in the ambient air, may alter this equality of proportion betwixt them, and make one ſtronger then the other; therefore to prevent this, the Ancients did hide theſe lamps in ſome caverns of the earth, or cloſe monuments: And hence is it, that at the opening of theſe, the admiſſion of new air unto the lamp does uſually cauſe ſo great an inequality betwixt the flame and the oyle, that it is preſently extinguiſhed.

But ſtill the greateſt difficulty remains, how to make any ſuch exact proportion betwixt an unctuous humour, and ſuch an active quality, as the heat of fire, or this equality being

ing made, it is yet a further difficulty, how it may bee preserved. To which purpose, *Licetus* thinkes it possible to extract an inflamable oyl from the stone *Asbestus*, *Amiantus*, or the metall gold, which being of the same pure and homogeneous nature with those bodies, shall be so proportioned unto the heat of fire, that it cannot be consumed by it, but being once inflamed should continue for many ages, without any sensible diminution.

If it be in the power of Chymistry to perform such strange effects, as are commonly experimented in that which they call *aurum fulminans*, one scruple of which shall give a lowder blow, & be of greater force in descent, then half a pound of ordinary gunpowder in ascent; why may it not be as feasible by the same art to extract such an oyl as is here enquired after: Since it must needs be more difficult to make a fire which of its owne inclination shall tend downewards, then to contrive such an unctuous

ctuous liquour, wherein fire ſhall be maintained for many years without any new ſupply.

Thus have I briefly ſet down the relations and opinions of divers learned men concerning theſe perpetuall lamps; of which, though there have been ſo many ſundry kinds, and ſeverall ways to make them, (ſome being able to reſiſt any violence of weathers, others being eaſily extinguiſhed by any little alteration of the air, ſome being incloſed round about within glaſſe, others being open;) yet now they are all of them utterly periſhed amongſt the other ruines of time; and thoſe who are moſt verſed in the ſearch after them have onely recovered ſuch dark conjectures, from which a man cannot clearly deduce any evident principle that may encourage him to a particular triall.

CAP.

Cap. XIII.

Concerning ſeverall attempts of contriving a perpetuall motion by magneticall virtues.

THe ſecond way whereby the making of a perpetuall motion hath been atttempted, is by magneticall virtues; which are not without ſome ſtrong probabilities of proving effectuall to this purpoſe: eſpecially when we conſider that the heavenly revolutions, (being as the firſt pattern imitated and aimed at in theſe attempts) are all of them performed by the help of theſe qualities. This great orb of earth, and all the other planets being but as ſo many magneticall globes endowed with ſuch various and continuall motions, as may be moſt agreeable to the purpoſes for which they were intended. And therefore moſt of the Authours, who treat concerning this invention, do agree, that the likelieſt way to effect it, is by theſe kind of qualities.

It was the opiniō of *Pet: Peregrinus*, & there is an example pretended for it in *Betttinus* (*Apiar.9.Progym.5.pro.11.*) that a magneticall globe or terella, being rightly placed upon its poles, would of it ſelf have a conſtant rotation, like the diurnall motion of the earth; But this is commonly exploded, as being againſt all experience.

Gilbert de Magnet. Cabæus Philoſ. Magnet. l.4.c.20.

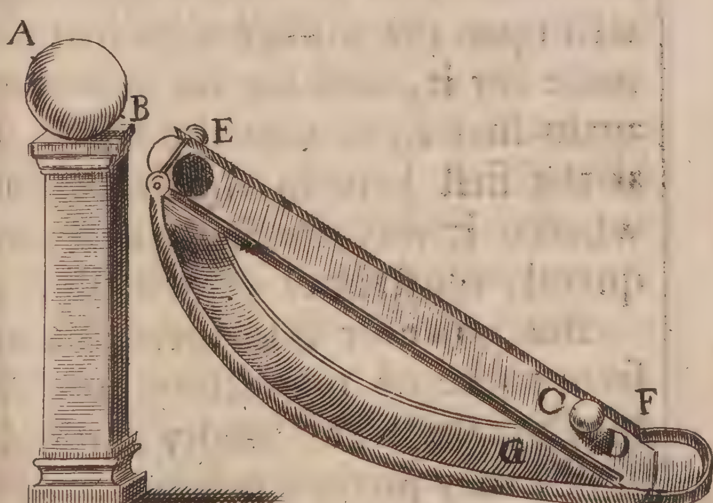
Others think it poſſible, ſo to contrive ſeverall pieces of ſteel, and a loadſtone, that by their continuall attraction and expulſion of one another, they may cauſe a perpetuall revolution of a wheel; Of this opinion were [a] *Taiſner*, [b] *Pet. Peregrinus*, and [c] *Cardan*, out of *Antonius de Fantis*. But D. *Gilbert*, who was more eſpecially verſed in magneticall experiments, concludes it to be a vain and groundleſſe fancy.

Athanaſ. Kircher, de Arte Magnet. l.1. par. 2. prop. 13. Item l.2. p.4.

[a] *Tract. de motu continuo.*
[b] *De Rota perpetui motus. par. 2. c.3.*
[c] *De Variet. rerū l.9. c.48.*
De magnet. l.2. c.35

But amongſt all theſe kind of inventions, that is moſt likely, wherein a loadſtone is ſo diſpoſed, that it ſhall draw unto it on a reclined plane, a bullet of ſteel; which ſteele, as it aſcends

ſcends neer to the loadſtone, may be contrived to fall down through ſome hole in the plane, and ſo to return unto the place from whence at firſt it began to move; and being there, the loadſtone will again attract it upwards, till coming to this hole it will fall down again: and ſo the motion ſhall be perpetuall, as may be more eaſily conceivable by this figure.



Suppoſe the loadſtone to be repreſented at $A\,B$, which though it have not ſtrength enough to attract the bullet C, directly from the ground, yet may doe it by the help of the plane $E\,F$; Now when the bullet is come to the top of this plane, its own gravity (which is ſuppoſed to exceed the ſtrength of the loadſtone) will make it fall into that hole at E: and the force it receives in this fall, will carry it with ſuch a violence unto the other end of this arch, that it will open the paſſage which is there made for it, and by its return will again ſhut it, ſo that the bullet, (as at the firſt) is in the ſame place, whence it was attracted, and conſequently muſt move perpetually.

But however this invention may ſeem to be of ſuch ſtrong probability, yet there are ſundry particulars which may prove it inſufficient; For,

1. This bullet of ſteele muſt firſt be touched and have its ſeverall poles, or elſe there can be little or no attraction of it. Suppoſe C in the ſteel

to be anſwerable unto *A* in the ſtone, and to *B*; In the attraction *C D*, muſt always be directed anſwerable to *A B*, and ſo the motion will be more difficult, by reaſon there can be no rotation or turning round of the bullet, but it muſt ſlide up with the line *C D*, anſwerable to the axis *A B*.

2. In its fall from *E* to *G*, which is *motus elementaris*, and proceeds from its gravity, there muſt needs be a rotation of it, and ſo 'tis ods, but it happens wrong in the riſe, the poles in the bullet, being not in the ſame direction to thoſe in the magnet; and if in this refluxe it ſhould ſo fall out, that *D* ſhould be directed towards *B*, there ſhould be rather a flight then an attraction, ſince thoſe two ends doe *repell* and not draw one another.

3. If the loadſtone *A B*, have ſo much ſtrength that it can attract the bullet in *F*, when it is not turned round, but does onely ſlide upon the plane, whereas its own gravity would roule it downwards: then it is evident,

the ſphere of its activity and ſtrength would be ſo increaſed when it approaches much neerer, that it would not need the aſſiſtance of the plane, but would draw it immediately to it ſelf, without that help, and ſo the bullet would not fal down through the hole, but aſcend to the ſtone, and conſequently ceaſe its motion. For if the loadſtone be of force enough to draw the bullet on the plane, at the diſtance *F B*, then muſt the ſtrength of it be ſufficient to attract it immediately unto it ſelfe, when it is ſo much neerer as *E B*. And if the gravity of the bullet be ſuppoſed ſo much to exceed the ſtrength of the Magnet, that it cannot draw it directly when it is ſo near, then will it not be able to attract the bullet up the plane when it is ſo much further off.

So that none of all theſe Magneticall experiments, which have been as yet diſcovered, are ſufficient for the effecting of a perpetuall motion, though theſe kind of qualities ſeem moſt conducible unto it, and per-

haps

haps hereafter it may be contrived from them.

CAP. XIV.

The ſeeming probability of effecting a continuall motion by ſolid weights in a hollow wheel or ſphere.

THe third way whereby the making of a perpetuall motion hath been attempted, is by the naturall affection of gravity; when the heavineſſe of ſeverall bodies is ſo contrived, that the ſame motion which they give in their deſcent, may bee able to carry them up again.

But againſt the poſſibility of any ſuch invention, it is thus objected by *Cardan*; All ſublunary bodies have a direct motion either of aſcent or deſcent, which, becauſe it does refer to ſome tearm, therefore cannot be perpetuall, but muſt needs ceaſe, when it is arrived at the place unto which it naturally tends. *Subtil.l.17 De Var. Rerum l.9. c.48.*

I anſwer, though this may prove

that there is no naturall motion of any particular heavy body, which is perpetuall, yet it doth not hinder but that it is poſſible from them to contrive ſuch an artificiall revolution as ſhall conſtantly be the cauſe of it ſelf.

Thoſe bodies which may be ſerviceable to this purpoſe, are diſtinguiſhable into two kinds.

1. Solid and conſiſtent, as weights of metall, or the like.

2. Fluid or ſliding, as water, ſand, &c.

Both theſe ways have been attempted by many, though with very little or no ſucceſſe. Other mens conjectures in this kind you may ſee ſet down by divers Authours. It would be too tedious to repeat them over, or ſet forth their draughts. I ſhall onely mention two new ones, which (if I am not over partiall) ſeem altogether as probable, as any of theſe kinds that have been yet invented; and til experience had diſcovered their defect and inſufficiency, I did certainly

D. Flud. *Tract.* 2. *pars* 7. *l.* 2. *c.* 4. *et* 7.

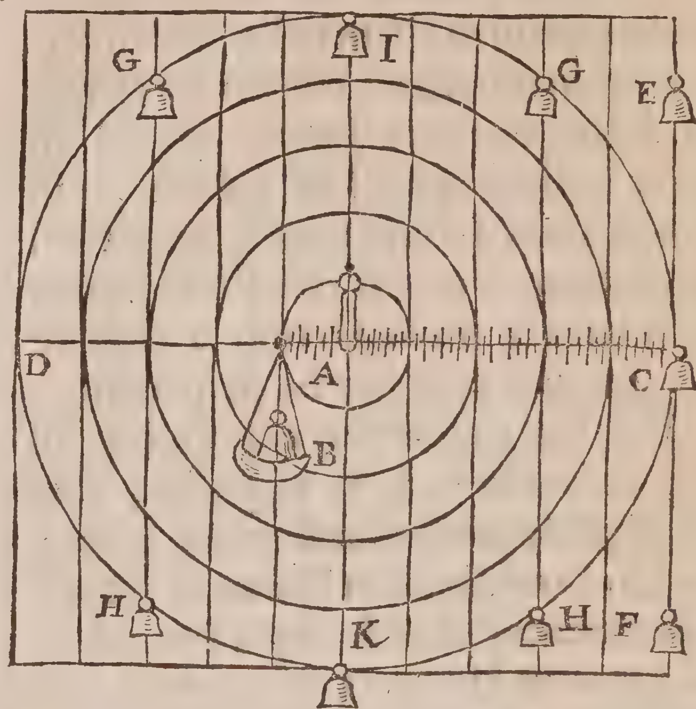
tainly

tainly conclude them to be infallible.

The firſt of theſe contrivances was by ſolid weights being placed in ſome hollow wheel or ſphere, unto which they ſhould give a perpetuall revolution. For (as the Philoſopher hath largely proved) only a circular motion can properly be perpetuall. *Ariſt.Phyſ. l.8.c.12.*

But for the better conceiving of this invention, it is requiſite, that we rightly underſtand ſome principles in *Trochilicks*, or the art of wheel-inſtruments; As chiefly, the relation betwixt the parts of a wheel, and thoſe of a ballance: the ſeverall proportions in the Semidiameter of a wheel, being anſwerable to the ſides in a ballance, where the weight is multiplyed according to its diſtance from the center. *Ariſt.Mechan.c.2. De ratione libræ ad circulum.*

Thus



Thus ſuppoſe the center to be at *A*, and the Diameter of the wheel *D C*, to be divided into equall parts (as is here expreſſed) it is evident according to the former ground, that one pound at *C*, will equiponderate to five pound at *B*, becauſe there is ſuch a proportion betwixt their ſeverall diſtances from the Center. And it is not materiall whether or no theſe ſeverall weights be placed horizontally, for though *B* do hang lower then

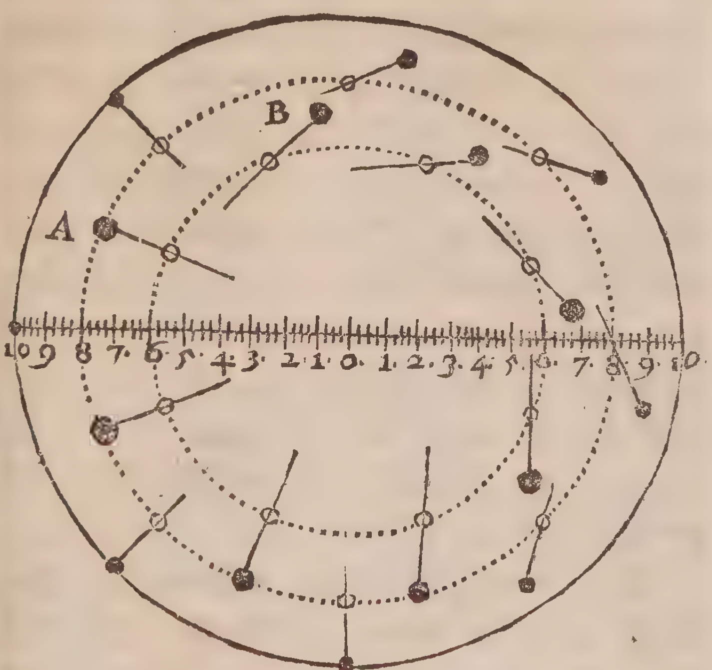
then *C*, yet this does not at all concern the heavineſſe, or though the plummet *C*, were placed much higher then it is at *E*, or lower at *F*, yet would it ſtill retain the ſame weight which it had at *C*, becauſe theſe plummets (as is the nature of all heavy bodies) doe tend downewards by a ſtreight line: So that their ſeverall gravities are to be meaſured by that part of the horizontall Semidiameter, which is directly either below or above thẽ. Thus when the plummet *C*, ſhall be moved either to *G* or *H*, it wil loſe $\frac{2}{5}$ of its former heavineſſe, and bee equally ponderous as if it were placed in the ballance at the number 3, and if we ſuppoſe it to be ſituated at *I* or *K*, then the weight of it will lie wholly upon the Center, and not at all conduce to the motion of the wheel on either ſide. So that the ſtreight lines which paſſe through the diviſions of the diameter, may ſerve to meaſure the heavineſſe of any weight in its ſeverall ſituations.

Theſe things throughly conſidered, it

it ſeems very poſſible and eaſie for a man to contrive the plummets of a wheel, that they may be always heavier in their fall, then in their aſcent; and ſo conſequently that they ſhould give a perpetuall motion to the wheel it ſelf: Since it is impoſſible for that to remain unmoved, as long as one ſide in it is heavier then the other.

For the performance of this, the weights muſt be ſo ordered, 1. That in their deſcent they may fall from the Center, and in their aſcent may riſe neerer to it. 2. That the fall of each plummet may begin the motion of that which ſhould ſucceed it. As in this following Diagram.

Where



Where there are 16 plummets, 8 in the inward circle, and as many in the outward, (the inequality being to ariſe from their ſituation, it is therefore moſt convenient that the number of them be even.) The eight inward plummets are ſuppoſed to be in themſelves ſo much heavier then the other, that in the wheel they may be of equall weight with thoſe above them, and then the fall of theſe will bee of ſufficient force to bring down

down the other. For example, if the outward be each of them 4 ounces, then the inward must be 5, because the outward is distant from the center 5 of those parts, whereof the inward is but 4. Each paire of these weights should be joyned together by a litle string or chain, which must be fastned about the middle betwixt the bullet and the center of that plummet, which is to fall first, and at the top of the other.

When these bullets in their descent are at their farthest distance from the center of the wheel, then shall they be stopped, and rest on the pins placed to that purpose; and so in their rising, there must be other pins to keep them in a convenient posture and distance from the center, lest approaching too neere unto it, they thereby become unfit to fall, when they shall come to the top of the descending side.

This may be otherwise contrived with some different circumstances, but they will all redound to the same effect.

effect. By ſuch an engine it ſeemes very probable, that a man may produce a perpetuall motion. The diſtance of the plummets from the center increaſing their weight on one ſide, and their being tyed to one another, cauſing a conſtant ſucceſſion in their falling.

But now, upon experience I have found this to be fallacious, & the reaſon may ſufficiently appear by a calculation of the heavines of each plummet, according to its ſeveral ſituation; which may eaſily be done by thoſe perpendiculars that cut the diameter, (as was before explained, and is here expreſſed in five of the plummets on the deſcending ſide.) From ſuch a calculation it will be evident, that both the ſides of this wheel will equiponderate, and ſo conſequently that the ſnppoſed inequality, whence the motion ſhould proceed, is but imaginary and groundleſſe. On the deſcending ſide, the heavineſſe of each plummet may be meaſured according to theſe numbers, (ſuppoſing the diameter

ameter of the wheel to be divided into twenty parts, and each of those subdivided into four.)

The outward plummets.

7	0	*The sum* 24.
10	0	
7	0	

The inward plummets.

1	0	*The sum* 19.
7	2	
7	2	
3	0	

On the ascending side the weights are to be reckoned according to these degrees.

The outward.

1	3	*The sum* 24.
7	2	
9	0	
5	3	
0	0	

The inward.

4	1	*The sum* 19.
7	0	
5	2	
2	1	

The summe of which last numbers is equall with the former, and therefore both the sides of such a wheele, in this situation will equiponderate.

If

If it be objected, that the plummet *A* should bee contrived to pull down the other at *B*, and then the descending side will be heavier then the other.

For answer to this, it is considerable,

1. That these bullets towards the top of the wheel, cannot descend till they come to a certain kind of inclination.

2. That any lower bullet hanging upon the other above it, to pull it down, must be conceived, as if the weight of it were in that point where its string touches the upper, at which point this bullet will be of lesse heavinesse in respect of the wheel, then if it did rest in its own place: So that both the sides of it in any kind of situation may equiponderate.

Cap. XV.

Of composing a perpetuall motion by fluid weights. Concerning Archimedes *his water-screw. The great probability of accomplishing this inquiry by the help of that, with the fallibleneß of it upon experiment.*

THat which I shall mention as the last way, for the triall of this experiment, is by contriving it in some water instrument; which may seem altogether as probable and easie as any of the rest, because that element by reason of its fluid and subtle nature (whereby of its own accord it searches out the lower and more narrow passages) may be most pliable to the mind of the artificer. Now the usuall means for the ascent of water is either by *Suckers* or *Forces*, or something equivalent thereunto; Neither of which may be conveniently applied unto such a work as this, because there is required unto each of them so much or more strength, as may be answerable

ble to the full weight of the water that is to be drawn up; and then besides, they move for the most part by fits and snatches, so that it is not easily conceivable, how they should conduce unto such a motion, which by reason of its perpetuity must bee regular and equall.

But amongst all other ways to this purpose, that invention of *Archimedes* is incomparably the best, which is usually called *Cochlea*, or the *water-screw*, being framed by the helicall revolution of a cavity about a Cylinder. We have not any discourse from the Authour himself concerning it, nor is it certain whether he ever writ any thing to this purpose. But if he did, yet as the injury of time hath deprived us of many other his excellent workes, so likewise of this, amongst the rest.

Athenæus speaking of that great ship built by *Hiero*, in the framing of which, there were 300 Carpenters employed for a year together, besides many other hirelings for carriages, *Dipnosoph. l.5.*

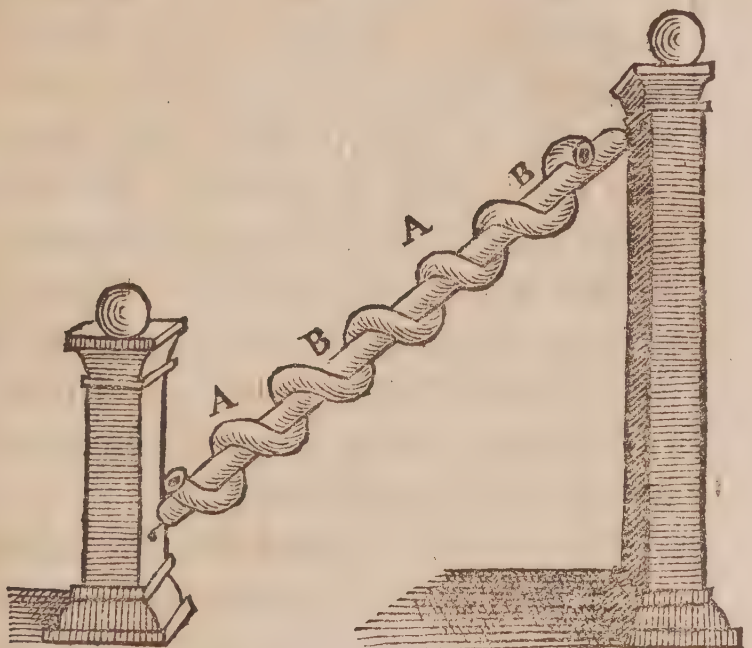
and ſuch ſervile works, mentions this inſtrument as being in ſtead of a pump for that vaſt ſhip, by the help of which, one man might eaſily and ſpeedily drain out the water, though it were very deep.

Biblioth. l.1. *Diodorus Siculus* ſpeaking of this engine, tels us, that *Archimedes* invented it when hee was in Ægypt, and that it was uſed in that Country for the draining of thoſe pits and lower grounds, whence the waters of *Nilus* could not return. Φιλοτέχνου δ' ὄντος τοῦ ὀργάνου καθ' ὑπερβολὴν, (ſaith the ſame Authour.) It being an engine ſo ingenious and artificiall, as cannot be ſufficiently expreſſed or commended. And ſo (it ſhould ſeeme) the Smith in Millain conceived it to be, who having without any teaching or information found it out, and therefore thinking himſelf to be the firſt inventer, fell mad with the meer joy of it. *Cardan Subt l.1. De ſapient. l.5.*

The nature and manner of making this, is more largely handled by *Vitruvius*. *Architect. l.10.c.11.*

The

The figure of it is after this manner.



Where you ſee there is a Cylinder *AA*, and a ſpirall cavity or pipe twining about it, according to equall revolutions *BB*. The axis and centers of its motions are at the points *C D*, upon which being turned, it will ſo happen that the ſame part of the pipe which was now lowermoſt, will preſently become higher, ſo that the water does aſcend by deſcending; aſcending in compariſon to the whole inſtrument, and deſcending in reſpect of its ſeverall parts. This being one of the ſtrangeſt wonders amongſt thoſe many, wherein theſe Mathematicall arts doe abound, that a heavy body ſhould riſe by falling down, and the farther it paſſes by its own naturall motion of deſcent, by ſo much higher ſtill ſhall it aſcend; wch though it ſeem ſo evidently to contradict all reaſon and Philoſophy; yet in this inſtrument it may be manifeſted both by demonſtration and ſenſe.

This pipe or cavity for the matter of it, cannot eaſily be made of metall, by reaſon of its often turnings; but for triall, there might bee ſuch a cavity, cut in a columne of wood, and afterwards covered over with tinne plate.

For the form and manner of making this ſcrew, *Vitruvius* does preſcribe theſe two rules:

1. That there muſt be an equality obſerved betwixt the breadth of the pipe, and the diſtance of its ſeverall circumvolutions.

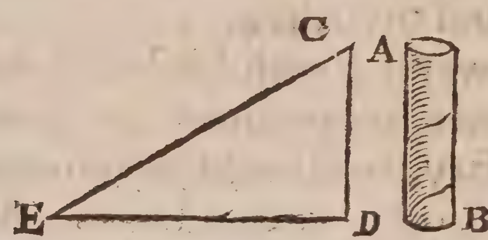
2. That there muſt be ſuch a pro-

portion betwixt the length of the instrument, and its elevation, as is answerable to the *Pythagoricall Trigon.* If the Hypotenusall, or Screw be 5, the perpendicular or elevation must be 3, and the basis 4.

David Rivalt. Com. in Archim. opera extern.

However (with his leave) neither of these proportions are generally necessary, but should be varied according to other circumstances. As for the breadth of the pipe in respect of its revolutions, it is left at liberty, and may bee contrived according to the quantity of water which it should contain. The chief thing to be considered is the obliquity or closenesse of these circumvolutions. For the nearer they are unto one another, the higher may the instrument be erected; there being no other guide for its true elevation but this.

And because the right understanding of this particular is one of the principall matters that concerns the use of this engine, therefore I shall endeavour with brevity and perspicuity to explain it. The first thing to be inquired after is what kind of inclination these Helicall revolutions of the cylinder have unto the Horizon, which may be thus found out.

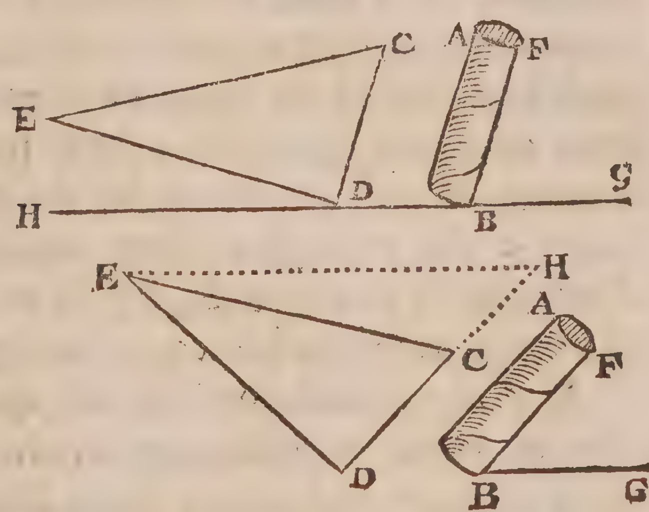


Let *A B* represent a Cylinder with two perfect revolutions in it, unto which cylinder the perpendicular line *C D* is equall: the basis *D E* being supposed to bee double unto the compasse or circumference of the cylinder. Now it is certain that the angle *C E D*, is the same with that by which the revolutions on the cylinder are framed, and that the line *E C*, in comparison to the basis *E D*, does shew the inclination of these revolutions unto the Horizon. The grounds and demonstration of this are more fully set downe by *Guidus Vbaldus*, in his Mechanicks, and that

other

other Treatiſe *De Cochlea*, which he writ purpoſely for the explication of this inſtrument, where the ſubtilties of it are largely and excellently handled.

Now if this Screw which was before perpendicular, bee ſuppoſed to decline unto the Horizon by the angle *F B G*, as in this ſecond figure;



then the inclination of the revolutions in it, will be increaſed by the angle *E D H*, though theſe revolutions will ſtill remain in a kind of aſcent, ſo that water cannot bee turned through them.

But

But now, if the Screw be placed ſo far declining, that the angle of its inclination *F B G*, be leſſe then the angle *E C D*, in the triangle, as in this other Diagram under the former; then the revolutions of it will deſcend to the Horizon, as does the line *E C*, and in ſuch a poſture, if the Screw be turned round, water will aſcend through its cavity. Whence it is eaſie to conceive the certain declination wherein any Screw muſt bee placed for its owne conveyance of water upwards. Any point betwixt *H* and *D*, being in deſcent, but yet the more the Screw declines downwards towards *D*, by ſo much the more water will be caried up by it.

If you would know the juſt quantity of water which every revolution does contain and carry, according to any inclination of the cylinder, this may be eaſily found by aſcribing on it an *Ellipſis*, parallel to the Horizon; which *Ellipſis* will ſhew how much of the revolution is empty, and how much full.

See a further explication of this in *V-baldus de Cochlea*, *l.* 2 *Prop.* 25.

The

The true inclination of the Screw being found, together with the certain quantity of water which every *helix* does contain; it is further considerable, that the water by this instrument does aſcend naturally of it ſelf without any violence or labour, and that the heavineſſe of it does lie chiefly upon the centers or axis of the cylinder, both its ſides being of equall weight (ſaith *Vbaldus*;) So that (it ſhould ſeem) though we ſuppoſe each revolution to have an equall quantity of water, yet the Screw will remain with any part upwards (according as it ſhall be ſet) without turning it ſelf either way. And therefore the leaſt ſtrength being added to either of its ſides, ſhould make it deſcend, according to that common maxime of *Archimedes*; any addition will make that which equiponderates with another, to tend downwards.

Ibid.l.3. prop.4.

De Æquipond. Suppoſ.3.

But now, becauſe the weight of this inſtrument, and the water in it does leane wholly upon the axis, hence

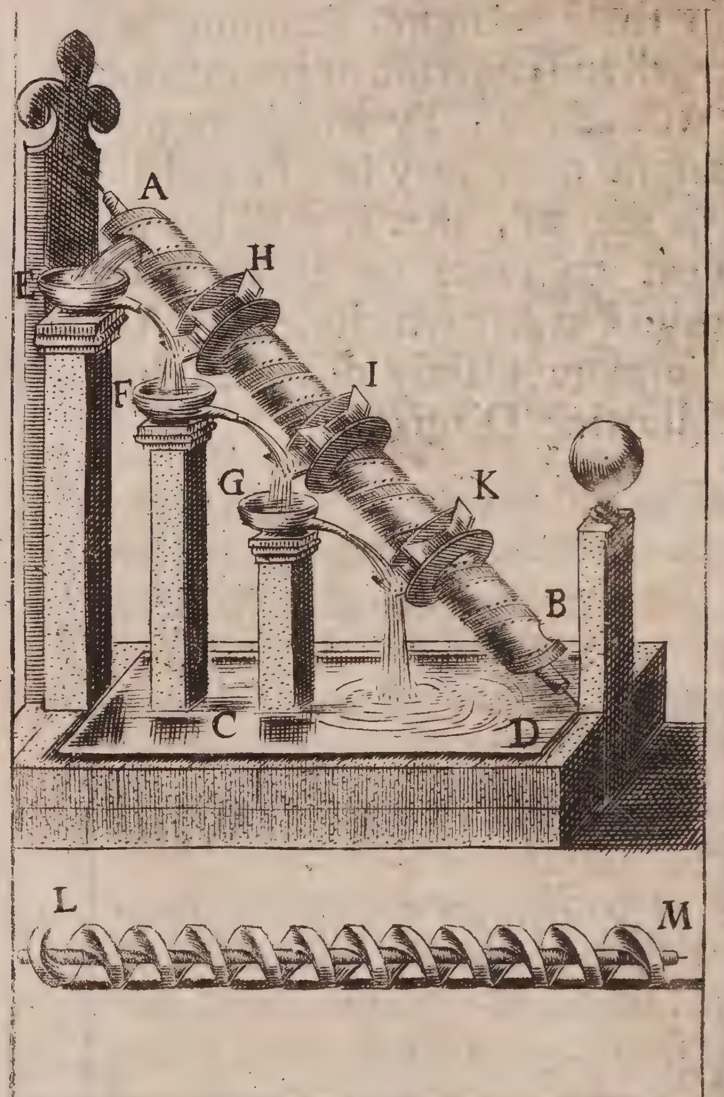
hence is it (ſaith *Vbaldus*) that the grating and rubbing of theſe axes againſt the ſockets wherein they are placed, will cauſe ſome ineptitude and reſiſtency to that rotation of the cylinder, which would otherwiſe enſue upon the addition of the leaſt weight to any one ſide; But (ſaith the ſame Authour) any power that is greater then this reſiſtency which does ariſe from the axis, will ſerve for the turning of it round.

Theſe things conſidered together, it wil hence appear, how a perpetual motion may ſeem eaſily contrivable. For if there were but ſuch a water-wheel made on this inſtrument, upon which the ſtream that is carried up, may fall in its deſcent, it would turn the Screw round, and by that means convey as much water up, as is required to move it, ſo that the motion muſt needs be continuall, ſince the ſame weight which in its fall does turn the wheel, is by the turning of the wheel carried up again.

Or if the water falling upon one wheel

wheel would not be forcible enough forthis effect, why then there might be two or three, or more, according as the length and elevation of the instrument will admit ; By which means the weight of it may bee so multiplied in the fall, that it shall bee equivalent to twice or thrice that quantity of water which ascends. As may be more plainly discerned by this following Diagram.

Where


A
H
E
F
I
G
K
B
C
D
L
M

Where the figure *L M*, at the bottome does represent a wooden cylinder with helicall cavities cut in it, which at *A B*, is supposed to be covered ever with tin plates, and three water-wheels upon it *H I K*. The lower cistern which contains the water being *C D*. Now this cylinder being turned round, all the water which frō the cistern ascends through it, will fall into the vessell at *E*, and from that vessell being conveyed upon the water-wheel *H*, shall consequently give a circular motion to the whole Screw: Or if this alone should bee too weak for the turning of it, then the same water which fals from the wheel *H*, being received into the other vessell *F*, may from thence againe descend on the wheel *I*; by which means the force of it will be doubled. And if this be yet insufficient, then may the water which fals on the second wheel *I*, be received into the other vessell *G*, and from thence again descend on the third wheel at *K*: and so for as many

There is another like contrivance to this purpose in *Pet:Bettin. Apiar.*4. *Progym.*1. *Prop.*10. but with much lesse advantage then 'tis here proposed.

many other wheeles, as the instrument is capable of. So that besides the greater distance of these three streams from the center or axis, by which they are made so much heavier, & besides, that the fal of this outward water is forcible and violent, whereas the ascent of that within is naturall; Besides all this, there is thrice as much water to turn the Screw, as is carried up by it.

But on the other side, if all the water falling upon one wheel, would be able to turn it round, then half of it would serve with two wheels; and the rest may be so disposed of in the fall, as to serve unto some other usefull delightfull ends.

When I first thought of this invention, I could scarce forbear with *Archimedes* to cry out εὕρηκα εὕρηκα; It seeming so infallible a way for the effecting of a perpetuall motion, that nothing could bee so much as probably objected against it: But upon triall and experience I finde it altogether insufficient for any such

purpose

purpose, and that for these two reasons:

1. The water that ascends will not make any considerable stream in the fall.

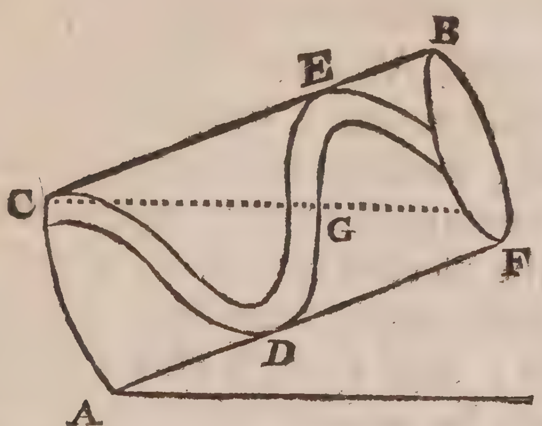
2. This stream (though multiplied) will not bee of force enough to turn about the Screw.

1. The water ascends gently and by intermissions, but it fals continuately and with force; each of the three vessels being supposed full at the first, that so the weight of the water in them might adde the greater strength and swiftnesse to the streames that descend from them; Now this swiftnesse of motion will cause so great a difference betwixt them, that one of these little streams may spend more water in the fall, then a stream six times bigger in the ascent, though wee should suppose both of them to be continuate; How much more then, when as the ascending water is vented by fits and intermissions, every circumvolution voiding onely so much as is con-

tained in one *Helix*? And in this particular, one that is not verſed in theſe kind of experiments, may bee eaſily deceived.

But ſecondly, though there were ſo great a diſproportion, yet notwithſtanding the force of theſe outward ſtreams, might well enough ſerve for the turning of the Screw, if it were ſo that both its ſides would equiponderate the water being in them (as *Vbaldus* hath affirmed.) But now upon farther examination, we ſhall find this aſſertion of his, to be utterly againſt both reaſon and experience. And herein does conſiſt the chief miſtake of this contrivance. For the aſcending ſide of the Screw is made by the water contained in it ſo much heavier then the deſcending ſide, that theſe outward ſtreams thus applied, will not be of force enough to make them equiponderate, much leſſe to move the whole. As may be more eaſily diſcerned by this figure.

Where



Where *A B*, repreſents a Screw covered over, *C D E*, one *Helix* or revolution of it, *C D*, the aſcending ſide, *E D* the deſcending ſide, the point *D* the middle. The Horizontall line *C F*, ſhewing how much of the *Helix* is filled with water, *viz.* of the aſcending ſide, from *C* the beginning of the *Helix* to *D* the middle of it; and on the deſcending ſide, from *D* the middle, to the point *G*, where the Horizontall does cut the Helix. Now it is evident that this later part *D G*, is nothing neare ſo much, and conſequently not ſo heavy as the other *D C*. And thus is it in all the other revolutions, which as they are either more or larger, ſo will the difficulty of this motion bee increaſed. Whence it will appeare, that the outmard ſtreams which deſcend, muſt be of ſo much force as to countervail all that weight whereby the aſcending ſide in every one of theſe revolutions does exceed the other; And though this may be effected by making the water-wheels larger, yet then the motion will be ſo ſlow, that the Screw will not be able to ſupply the outward ſtreams.

There is another contrivance to this purpoſe mentioned by *Kircher de Magnete*, *l.2.p.4.* depending upon the heat of the ſun, and the force of winds, but it is liable to ſuch abundance of exceptions, that it is ſcarce worth the mentioning, and does by no means deſerve the confidence of any ingenuous artiſt.

Thus have I briefly explained the probabilities and defects of thoſe ſubtle contrivances, whereby the making of a perpetuall motion hath been attempted. I would be loath to diſcourage the enquiry of any ingenuous artificer.

artificer, by denying the poſſibility of effecting it with any of theſe Mechanicall helps; But yet (I conceive) if thoſe principles which concern the ſlowneſſe of the power in compariſon to the greatneſſe of the weight, were rightly underſtood, and throughly conſidered, they would make this experiment to ſeem (if not altogether impoſſible, yet) much more difficult then otherwiſe perhaps it will appear. However, the inquiring after it, cannot but deſerve our endeavours, as being one of the moſt noble amongſt al theſe Mechanicall ſubtilties. And (as it is in the fable of him who dugge the Vineyard, for a hid treaſure, though he did not finde the money, yet hee thereby made the ground more fruitfull, ſo) though we doe not attaine to the effecting of this particular, yet our ſearching after it may diſcover ſo many other excellent ſubtilties, as ſhall abundantly recompenſe the labour of our enquiry.

Treated of before, *l.1.c.*

And then beſides, it may be another encouragement to conſider the pleaſure of ſuch ſpeculations, which doe raviſh and ſublime the thoughts with more cleare angelicall contentments. *Archimedes* was generally ſo taken up in the delight of theſe Mathematicall ſtudies of this familiar *Siren*, (as *Plutarch* ſtyles them) that he forgot both his meat and drink, and other neceſſities of nature; nay, that he neglected the ſaving of his life, when that rude ſoldier in the pride and haſt of victory, would not give him leiſure to finiſh his demonſtration. What a raviſhment was that, when having found out the way to meaſure *Hiero's* Crown, he leaped out of the Bath, and (as if he were ſuddenly poſſeſt) ran naked up and down crying εὕρηκα εὕρηκα! It is ſtoried of *Thales* that in his joy and gratitude for one of theſe Mathematicall inventions, he went preſently to the Temple, and there offered up a ſolemn ſacrifice. And *Pythagoras* upon the like occaſion is related to have ſacrificed a hundred oxen. The juſtice of providence having

οἰκείας καὶ συνοίκου σειρῆνος. *Plutarch. Marcell.* *Ioan. Tzetzes, Chil. 2. Hiſt. 35.* *Valer. Maxim. l. 8. c. 7.*

ving ſo contrived it, that the pleaſure which there is in the ſucceſſe of ſuch inventions, ſhould be proportioned to the great difficulty and labour of their inquiry.

FINIS.